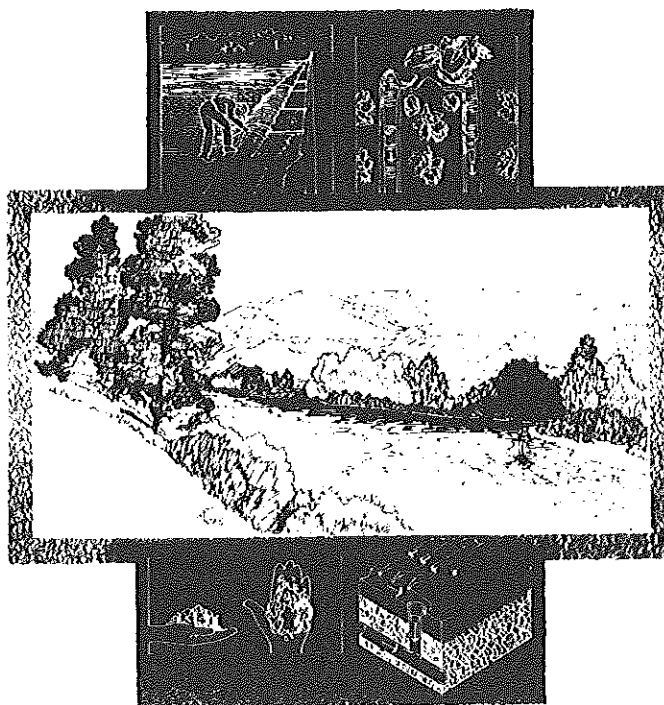


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MANAGEMENT PRACTICES for IRRIGATED AGRICULTURE



PREPARED BY

Washington State Department of Ecology
as an appendix to the
208 Irrigated Agriculture Water Quality Management Plan

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INTRODUCTION

This handbook was developed to assist Washington's irrigated farmers in identifying and applying management practices to improve the quality of irrigation return flows.

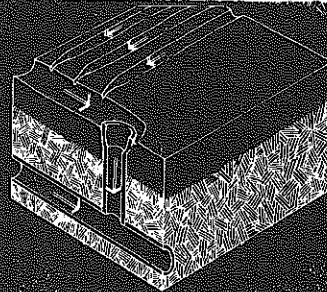
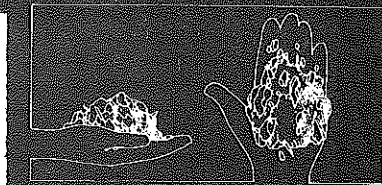
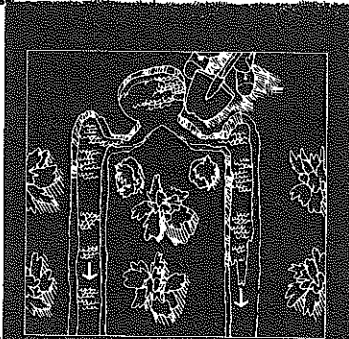
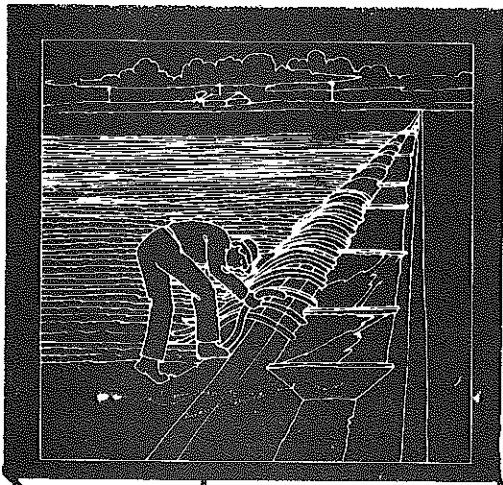
This handbook represents part of a federally required two-year water quality planning effort undertaken in this, and every, state. In accordance with Section 208 of the Federal Clean Water Act, farmers in Central Washington developed a process to implement these types of management practices as a means of reducing soil erosion and the adverse impacts of sediment on surface water quality.

The management practices presented here are intended as a "shopping list" of potential methods of irrigation management. Due to differences in topography, soil, and crops, these practices will not apply to every farm. A farmer may select or modify appropriate practices from this handbook or develop alternative practices to meet his irrigation needs. However, before undertaking any substantial investment of time, money, or labor, the farmer should discuss applicable practices with local conservation district specialists.

Because it was developed as an information/education tool for the 208 program, this handbook is not intended to replace detailed technical information.

In some cases, financial assistance may be available to aid the farmer in application of these or similar practices. Qualification for such programs (i.e., cost-sharing) should be discussed with the appropriate agency.

Irrigation Systems



IRRIGATION SYSTEMS

Proper irrigation system design provides the foundation for the subsequent application of many management practices for irrigation.

Before deciding upon a system for his field, a farmer should examine the advantages and disadvantages of each type of irrigation system. System design must not only address the crops' water needs, but must also be tailored to the field conditions. Although rill and sprinkler irrigation systems vary widely, certain criteria apply to all.

Applicability of Systems

Rill (or furrow) irrigation systems are generally applicable to all arable fields and crops grown in Washington. Problems may be experienced, however, where: 1) high intake rate soils make application of sufficient quantities of water difficult, or 2) steep slopes result in excessive soil and water losses.

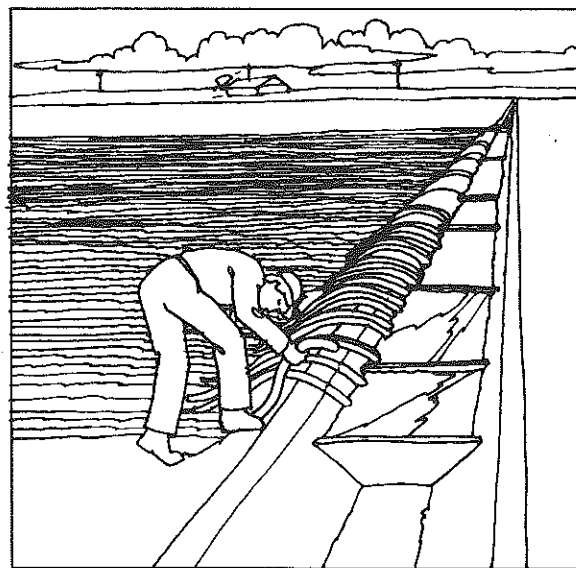
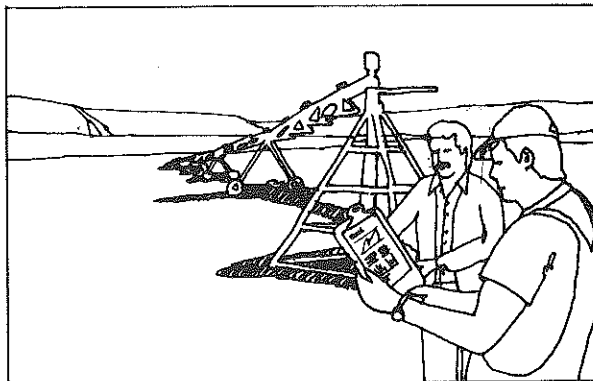
Sprinkler systems are also adaptable to most crops in Washington, the exceptions being crops, such as mint, which are adversely affected by sprinkling. Although sprinkler systems are especially suited to fields where high intake rate soils and steep slopes preclude the use of rill systems, careful evaluation is recommended before sprinklers are installed in these areas.

Capacity

Both rill and sprinkler systems should be designed with an application capacity to meet the peak irrigation scheduling demands of the field and crop.

Delivery

Where irrigation water is delivered to the system through a ditch, canal, or pipe, gates or valves should be installed to control the volume and direction of the inflow.



Accurate water application is made possible through the installation of measuring devices, such as weirs. Like control valves, measuring devices should be installed low enough to function when the water level in the delivery ditch is at a minimum.

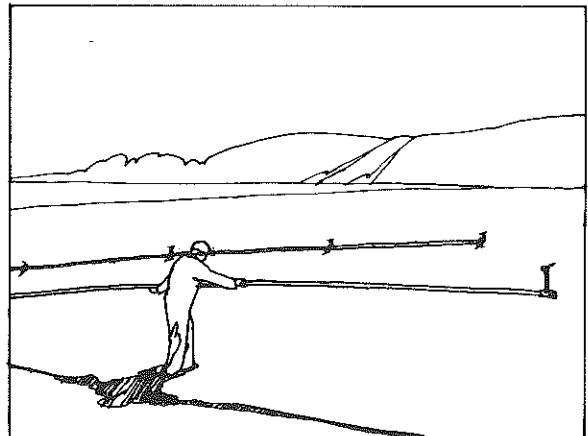
If the water must be screened before use, self-cleaning screens may be installed below the weirs. The water should fall one-half to one and one-half feet onto the screens to insure proper flushing of the screen.

Water Application

Both rill and sprinkler systems should be designed to apply water at a rate equal to or below the lowest intake rate of the soil irrigated. In addition to soil intake rates, soil erodibility and slope must be considered in determining proper application rates.

In rill systems, water control gates and valves insure uniform delivery of variable amounts of water to the furrows. The length and slope of the furrows must allow the lower end of the field to receive sufficient water, while minimizing water losses from deep percolation at the upper end. The volume and rate of water application should not cause erosion.

Due to the permanent nature of sprinkler systems, water application specifications should be designed into the irrigation system initially. Water application rates may be altered somewhat once a sprinkler system has been installed by controlling the water pressure or changing the nozzle size.



LAND LEVELING

Land leveling involves shaping the surface of a field to a planned grade to allow more uniform and efficient application of irrigation water. Eliminating irregularities in the field's surface can prevent waterlogging by improving surface drainage and can reduce the hazard of erosion.

Any irregularly sloped field may be leveled, provided the resulting soil depths will be adequate for crop production. Fields with shallow soils may be leveled if the leveling does not expose large areas of very shallow or highly permeable soil.

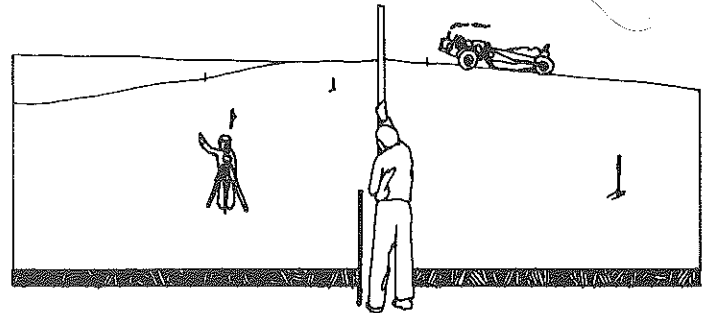
Land leveling should be planned as an integral part of the irrigation system. Where the application of more than one type of crop or practice is anticipated the field should be leveled to meet the requirements of the most restrictive crop or practice.

The elevation of the field after leveling should permit adequate water delivery and drainage. The highest point in the field should be at least four inches below the elevation of the water source. The slope of the field should be sufficient to allow drainage facilities to function properly.

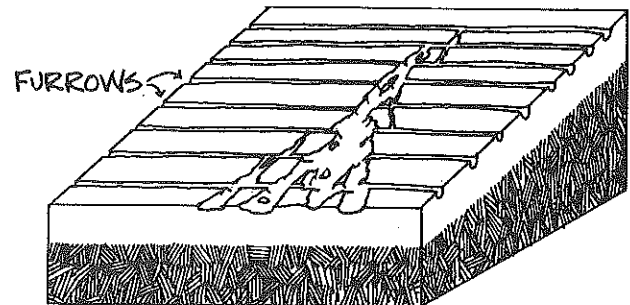
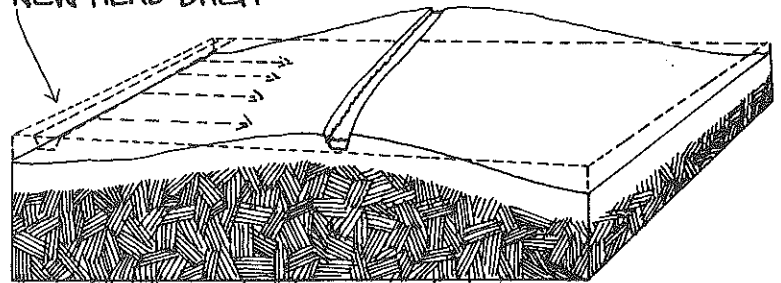
The length and slope of the furrows must be considered when the leveling is planned. The final conditions should allow the application of nonerosive stream volumes.

When irrigating across a slope, the degree of allowable side slope depends upon the stability of the soil and the length of the furrows. "Breakthroughs" across adjacent furrows should be prevented.

LEVELING TO A PLANNED GRADE



NEW HEAD DITCH



BREAKTHROUGHS FROM STEEP CROSS SLOPE

MAXIMUM NON-EROSIVE STREAMFLOWS			FURROWS*per CUBIC FT/SEC.
% SLOPE (ft/100')	FRESHLY CULTIVATED FURROWS	SUCKED or PRE-IRRIGATED FURROWS	FURROWS WITH COVER
0-.5%	<u>5-6.5</u> 70-90	<u>7-8.5</u> 53-65	<u>10-12</u> 38-45
.5-1%	<u>4-5</u> 90-113	<u>6-7</u> 65-75	<u>8-10</u> 45-56
1-2%	<u>3-4</u> 113-150	<u>5-6</u> 75-90	<u>6.5-8</u> 56-70
2-3%	<u>1.5-3</u> 150-300	<u>3.4-5</u> 90-129	<u>4.5-6.5</u> 70-100
3-5%	<u>.5-1.5</u> 300-900	<u>2-3.5</u> 129-225	<u>2.5-4.5</u> 100-180

* OR SIPHON TUBES

<u>5-6.5</u>	←	GALLONS PER MINUTE
<u>70-90</u>	←	FURROWS

LINED DITCHES

Lining canals, laterals, or head ditches with impervious materials, such as asphalt or concrete, prevents waterlogging, water losses through deep percolation, and erosion during the transport of water to the field. These problems are most acute in areas with high soil intake rates.

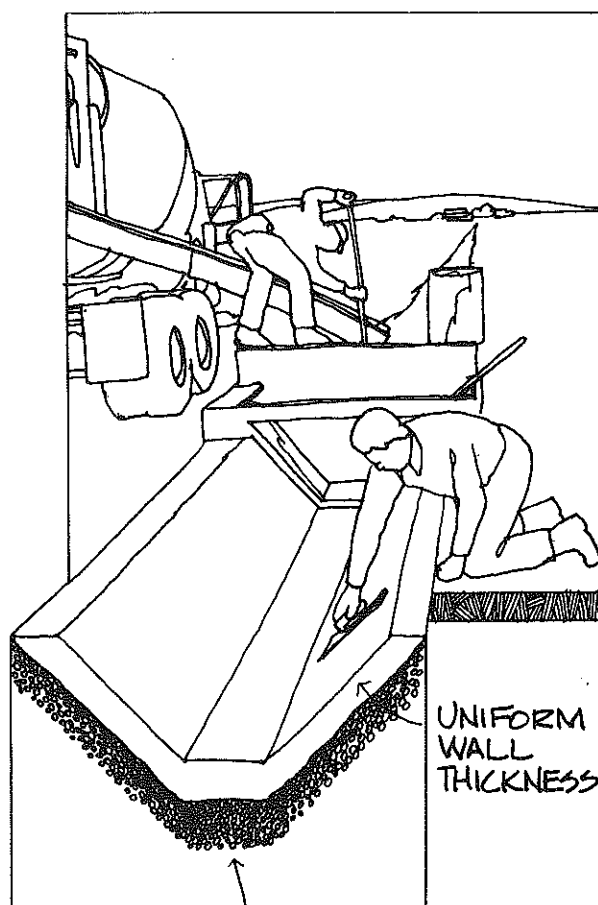
Lined ditches should be designed and installed with the assistance of an engineer or contracting firm familiar with technical specifications and local conditions.

Installation

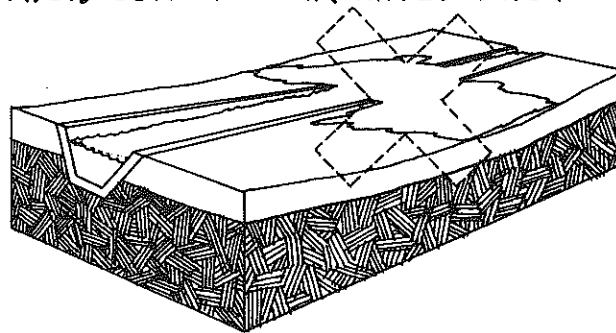
- 1) Linings should not be installed during cold weather.
- 2) Prior to installation, the ditch pad should be adequately compacted, contain adequate moisture to retain its shape, and be relatively free of debris.
- 3) Expansion joints in the lining should be adequately scored to prevent irreparable cracking.
- 4) The lining material should be of uniform thickness throughout the entire length of the ditch.

Design

- 1) The anticipated water level in lined ditches should be four to five inches above field elevation, and no higher than the water level at the inflow point.
- 2) Adequate height should be allowed between the water level and the top of the ditch to prevent overflowing.
- 3) The capacity of pipes under road crossings should be equal to the flow capacity of the lined ditch.
- 4) Lined ditches need not be reinforced in well-drained soils or where underground drainage facilities exist. Linings should be reinforced, however, where these conditions do not exist.
- 5) Nonreinforced lined ditches should not be installed in areas subject to severe frost heaving.



AVOID LOW SPOTS IN LINED DITCHES



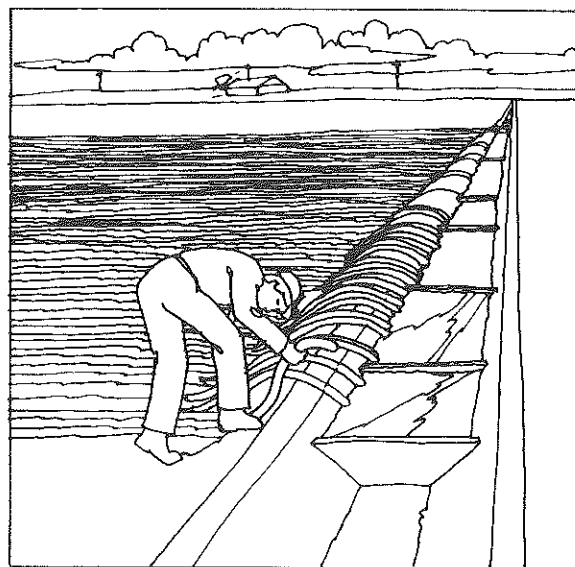
SIPHON TUBES

Siphon tubes are used to regulate the flow of water delivered from an open head ditch to the furrows. Portable checkdams may be used in conjunction with siphon tubes to facilitate siphoning by slowing the flow of water in steeper ditches.

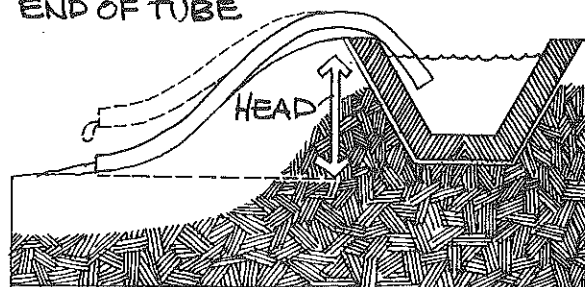
For siphon tubes to operate most efficiently, the water in the head ditches should remain at a fairly constant level and be relatively free of debris.

An irrigator can alter the volume of water delivered to the furrows by: 1) varying the number of siphon tubes to each furrow, 2) varying the diameter of the tubes by installing plugs in the tubes, and 3) raising or lowering the ends of the tubes to change the vertical distance between the water level in the ditch and the lower end of the siphon tube.

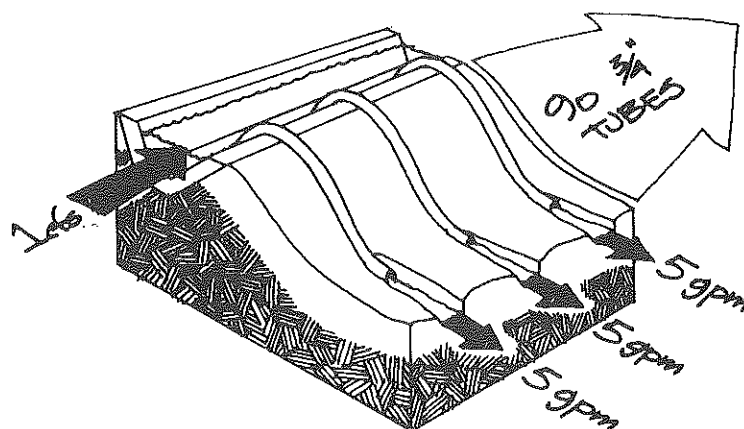
The amount of water delivered to the furrows should result in nonerosive streams. (See charts for suggested application rates.)



REDUCE FLOW (or HEAD)
BY RAISING FURROW
END OF TUBE



SAFE STREAM FLOWS FOR 1cfs






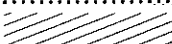
MAXIMUM NON-EROSIVE STREAMFLOWS			FURROWS* per CUBIC FT/SEC.
% SLOPE (#/100')	FRESHLY CULTIVATED FURROWS	SLICKED or PRE-IRRIGATED FURROWS	FURROWS WITH COVER
0-.5%	<u>5-6.5</u> 70-90	<u>7-8.5</u> 53-65	<u>10-12</u> 38-45
.5-1%	<u>4-5</u> 90-113	<u>6-7</u> 65-75	<u>8-10</u> 45-56
1-2%	<u>3-4</u> 113-150	<u>5-6</u> 75-90	<u>6.5-8</u> 56-70
2-3%	<u>1.5-3</u> 150-300	<u>3.4-5</u> 90-129	<u>4.5-6.5</u> 70-100
3-5%	<u>.5-1.5</u> 300-900	<u>2-3.5</u> 129-225	<u>2.5-4.5</u> 100-180

* OR SIPHON TUBES

<u>5-6.5</u> ←	GALLONS PER MINUTE
<u>70-90</u> ←	FURROWS

TUBE DISCHARGE (GPM)			
SIPHON TUBE DIAMETER (in.)	HEAD (inches)		
	2	4	6
$\frac{1}{2}$	1.3	1.8	2.1
$\frac{3}{4}$	3.5	5.0	6.0
.1	5.0	7.0	9.0
$\frac{1}{4}$	6.8	9.5	11.7
$\frac{1}{2}$	10.2	14.5	17.7
2	14.6	25.2	32.8

↑ 5%
SLOPES
0

	FRESHLY CULTIVATED
	SLICKED or PRE-IRRIGATED
	WITH COVER
	EROSIVE

BURIED PIPE WITH WATER CONTROL VALVES

In place of open head ditches, buried pipe can be used to transport water from the delivery point along the upper end of the field. Valves or risers on the buried pipe control the flow of water to the furrows. Transporting water directly to the furrows through buried pipe reduces water losses and erosion. This practice is especially beneficial under erosive field conditions, such as high intake rate soils or steep slopes.

On steeply sloped fields, buried pipe with risers may be run across the width of the field to split the field into shorter, more manageable furrow lengths. Normal farming operations can continue over the buried system.

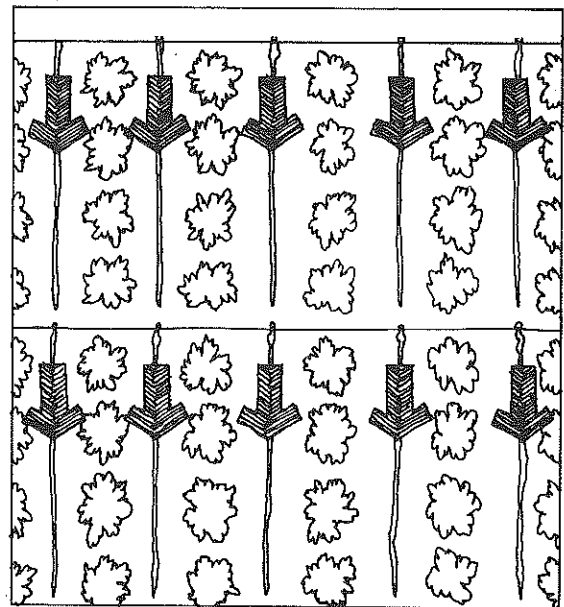
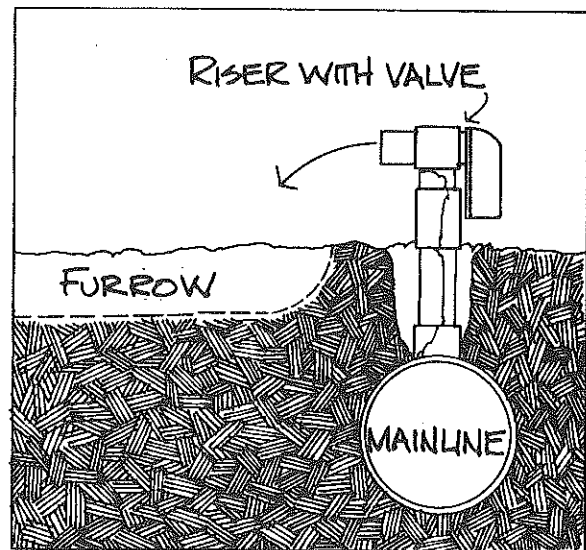
The installation of a buried pipe system should be planned with an engineer or agricultural contracting firm familiar with technical specifications and local conditions.

A buried pipe system should provide the stream volumes needed to meet the peak consumptive use demands of the most restrictive crop in the rotation. The system should also be capable of accommodating the needs of all anticipated irrigation operations, such as an increased number of streams and larger volumes required for irrigation of an entire field or differing water volumes necessitated by a change in cropping pattern.

Depending on the needs of each field and crop, several devices can be used to control the flow of water from the buried pipe to the furrows. These flow control devices include:

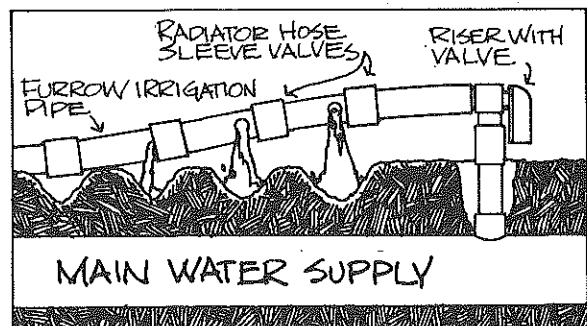
- 1) valves located on the pipe at or below the ground level,
- 2) above-the-ground risers with valves, and
- 3) perforated pipes which use slip hoses over the holes to control the flow of water.

Like all irrigation systems, a buried pipe system should apply water to each field in nonerosive volumes.



DIVIDED FIELD

PLASTIC PIPE FROM RISER FOR WATER CONTROL IN FURROWS



MAXIMUM NON-EROSIVE STREAMFLOWS				FURROWS* PER CUBIC FT/SEC.
% SLOPE (ft/100')	FRESHLY CULTIVATED FURROWS	SLICKED OR PRE-IRRIGATED FURROWS	FURROWS WITH COVER	
0-.5%	<u>5-6.5</u> 70-90	<u>7-8.5</u> 53-65	<u>10-12</u> 38-45	
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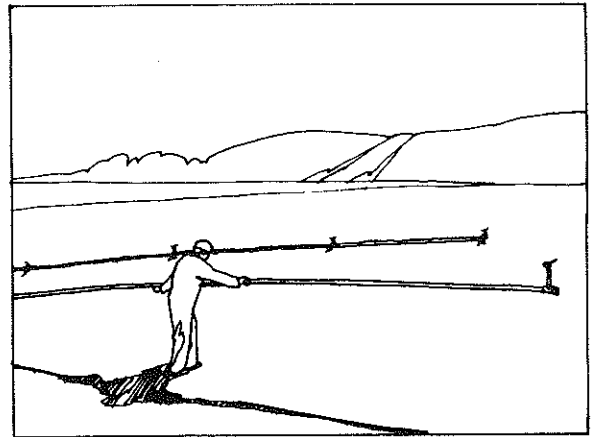
<u>5-6.5</u>	←	GALLONS PER MINUTE
<u>70-90</u>	←	FURROWS

HANDLINES

Portable, sectioned handlines may be used as a permanent, or sometimes temporary, irrigation system for virtually all types of arable fields and soils.

The mobility and arrangement flexibility of handline systems makes them well-suited for areas where the use of either rill or other sprinkler systems is difficult. Handlines may be employed on steep slopes, irregular-shaped fields, or where obstacles, such as powerlines, are present in the field. These systems are also effective as a method of irrigating temporary crops or young rill crops during their highly erosive periods.

Nozzles on handline systems should be designed so that water application volumes match soil intake rates. Sprinkler head spacing should insure uniform water application.

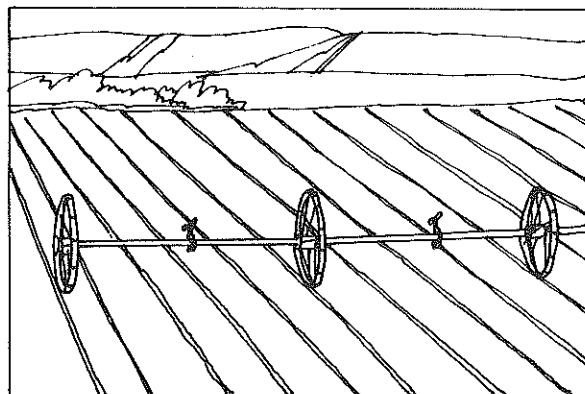


SIDE-ROLL WHEEL LINES

Side-roll wheel lines may be used on virtually all types of arable fields and soils. Although best suited for use on level, rectangular-shaped fields, sections of wheel line may be added or subtracted to accommodate variations in field dimensions. Their use is, however, limited by obstructions in the field, such as powerlines and drainage ditches, and by the height of the crop grown.

Wheel lines provide good water application since the sprinkler nozzle sizes can be designed independently to allow uniform or differing water application rates within a given field.

Because they are semiautomatic, wheel lines require less labor to operate than do handlines or rill systems.



CENTER PIVOT SYSTEMS

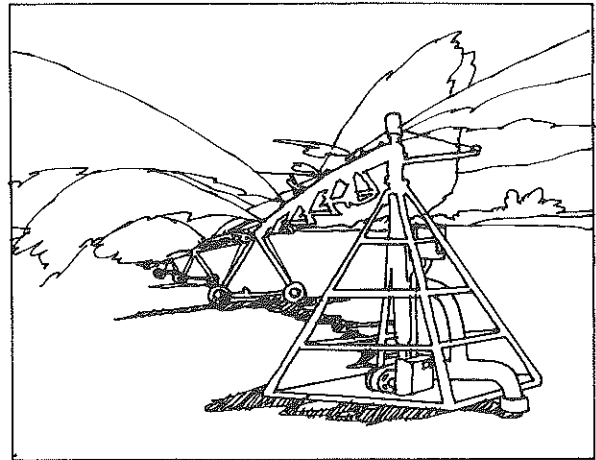
Center pivot sprinklers are automatic, circular systems capable of irrigating up to 160 acres in one rotation, depending on the length of the boom.

Due to the high water application rates at the extremities of the booms dictated by the speed of the system's movement, center pivots are best suited for use on level fields with high intake rate soils. These systems may pose an erosion hazard when applied on low and medium intake rate soils and/or on slopes of 5 percent or greater. The possibility of erosion is further increased by the continuous soil compaction in the wheel tracks.

Center pivot systems are applicable to most sprinkler-irrigated crops and, because of the high boom elevation, allow the growth of tall crops, such as corn.

Because these sprinkler systems are fully automatic, they require a minimal amount of labor, but, consequently, require a large amount of energy.

Initial capital investment for the installation of these systems is substantial. However, the amount of land irrigated by a single system reduces this investment to a low cost per acre. Maintenance requirements for this system may be high.



SOLID SET SYSTEMS

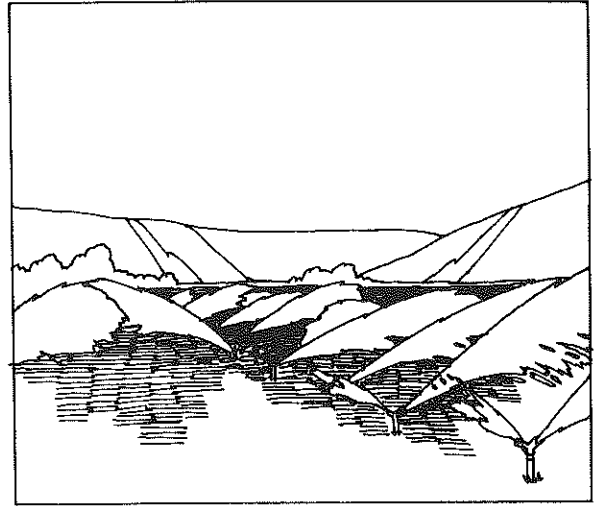
Solid set sprinklers may be permanently installed above or below the ground on virtually all field conditions and soil types. Due to their permanent nature, solid set systems are most applicable to orchards, vineyards, and other permanently planted fields.

By adjusting the sprinklers, water application rates in solid set systems may be permanently set or modified so that:

- 1) the water application volume matches the soil intake rate,
- 2) the sprinkler head spacing insures the desired (uniform or selected area) water application, or
- 3) the sprinkler elevation is appropriate for the crop and, if desired, allows for alternative uses, such as frost control and pesticide and herbicide application.

With the installation of timing devices, solid set systems may be partially or fully automated, reducing the amount of labor involved. Their operation does, however, require a considerable amount of energy.

These systems have a substantial installation cost per acre.



DRIP (TRICKLE) SYSTEMS

Drip, or trickle, irrigation systems apply water very slowly directly to the plant's root zone through emitter valves attached to permanently installed surface or buried pipe. (Trickle systems generally apply water at a slightly faster rate than drip systems.)

Drip systems cause very little, if any, erosion and can be used on all types of soil and field conditions. Because these systems operate on a minimal amount of pressure and virtually eliminate water losses, they are especially valuable in areas of short water supply. Water containing large amounts of suspended or settleable solids may, however, require extensive filtration before use to prevent clogging the system.

The permanent nature of drip systems makes them most applicable to orchards, vineyards, and other permanently planted crops and fields.

Depending on the crop's needs, anywhere from one to several emitters may be required for each plant to maintain the necessary high level of moisture in the soil throughout the growing period.

Drip systems may be modified to accommodate various crops' needs, field conditions, and the irrigator's desires.

Variations on these systems include:

- 1) porous tubing attached to the emitters,
- 2) double-walled piping with holes for greater flow control,
- 3) solenoid valves, timers, and tensiometers enabling system to operate automatically, and
- 4) modifications allowing application of fertilizers through system.

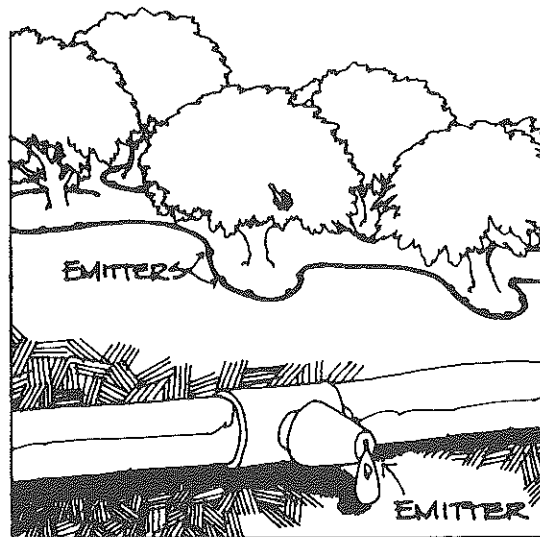


TABLE of PRECIPITATION (inches per hour)								
WETTED AREA (sq.ft)	EMITTER FLOW (gallons per hour)							
	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
4	.40	.60	.80	1.00	1.20	1.60	2.00	2.40
6	.25	.40	.50	.66	.80	1.06	1.30	1.60
8	.20	.30	.40	.50	.60	.80	1.00	1.20
10	.16	.25	.32	.40	.48	.64	.80	.96
12	.12	.20	.24	.33	.40	.53	.67	.80
15	.10	.16	.20	.27	.32	.43	.53	.64
20	.08	.12	.16	.20	.24	.32	.40	.48
30	.05	.08	.10	.13	.16	.21	.27	.32
40	.04	.06	.08	.10	.12	.16	.20	.24
50	.03	.05	.06	.08	.10	.13	.16	.19
60	.025	.04	.05	.07	.08	.10	.13	.16
80	.02	.03	.04	.05	.06	.08	.10	.12
100	.016	.025	.03	.04	.05	.06	.08	.10

Once the application rates have been determined, the delivery pipe size must be selected accordingly. The adjacent chart indicates approximate relationships between flow ranges and pipe sizes. Actual pipe sizes should be determined in consultation with a systems vendor or a competent engineer.

Because only the root zone of the primary crop receives water when a drip system is used, full cover crops must be capable of surviving without supplemental irrigation. Suitable varieties of cover grasses include:

- Intermediate Wheatgrass
- Whitmar Beardless Wheatgrass
- Sherman Big Bluegrass
- Nordan Crested Wheatgrass
- Siberian Wheatgrass
- Pubescent Wheatgrass
- Streambank Wheatgrass
- Hard Fescue

Extension Service, Soil Conservation Service, and conservation district personnel can assist in the choice of grasses best suited to meet individual soil types, seeding rates, etc.

MAINLINE and SUBMAIN PIPE SIZES	
FLOW RANGE	PIPE SIZE
0-3 GPM	$\frac{1}{2}$ " POLY
3-6 GPM	$\frac{3}{4}$ " PVC
6-10 GPM	1" PVC
10-30 GPM	1 $\frac{1}{2}$ " PVC
30-60 GPM	2" PVC
60-200 GPM	4" PVC
200-600 GPM	6" PVC

MODIFIED DRIP SYSTEMS

Like conventional drip systems, modified drip systems apply water very slowly directly to the plant's root zone through emitters attached to permanently installed surface or buried pipe. Modified drip systems, however, have adjustable emitter valves that allow the water application rate to be varied and the system to be flushed clean of debris.

Modified drip systems can be used on all types of soil and field conditions. Because they require a minimal amount of pressure to operate and virtually eliminate water losses, they are especially valuable in areas of short water supply. These systems can be easily flushed and are recommended for use in areas where suspended or settleable solids in the water may cause operational problems in conventional drip systems.

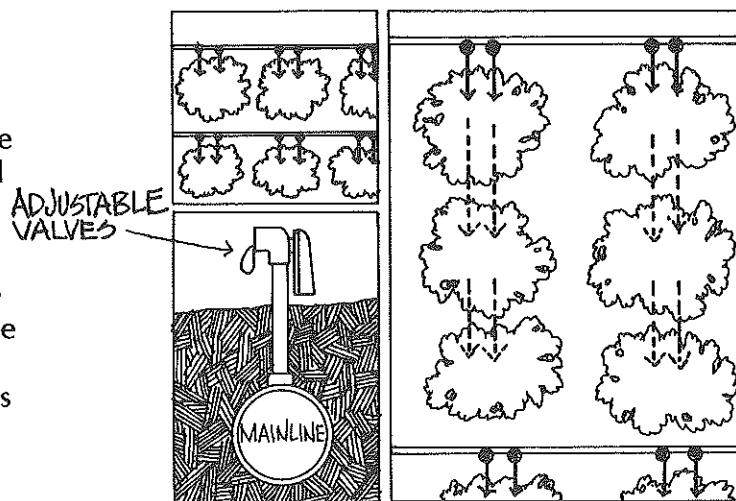
Depending on the crop's needs, one to several emitters may be required per plant to maintain the necessary soil moisture level throughout the growing period.

The application rates and irrigation time should be selected to meet the crop's needs. The following charts can be used as guidance in selecting appropriate application rates and irrigation times.

Once the application amounts and rates have been determined, the delivery pipe size must also be selected accordingly. The adjacent chart indicates approximate relationships between flow ranges and pipe sizes. Actual pipe sizes should be determined in consultation with a systems vendor or a competent engineer.

Modified drip systems may be partially or fully automated with the installation of timing devices.

Because only the root zone of the primary crop receives water, cover crops must be capable of surviving without supplemental irrigation. Suitable varieties of cover grasses include:



1 OR MORE VALVES PER TREE OR PLANT UTILIZED IN ORCHARD SHORTRUN SITUATION.

MAINLINE and SUBMAIN PIPE SIZES	
FLOW RANGE	PIPE SIZE
0-3 GPM	$\frac{1}{2}$ " POLY
3-6 GPM	$\frac{3}{4}$ " PVC
6-10 GPM	1" PVC
10-30 GPM	1 $\frac{1}{2}$ " PVC
30-60 GPM	2" PVC
60-200 GPM	4" PVC
200-600 GPM	6" PVC

Intermediate Wheatgrass
 Whitmar Beardless Wheatgrass
 Sherman Big Bluegrass
 Nordan Crested Wheatgrass
 Siberian Wheatgrass
 Pubescent Wheatgrass
 Streambank Wheatgrass
 Hard Fescue

Extension Service, Soil Conservation Service, and conservation district personnel can assist in the choice of grasses best suit to meet individual soil types, seeding rates, etc.

HOURS of IRRIGATION	APPLICATION AMOUNT (acre-in) 18" FURROW SPACE 100' RUN					
	APPLICATION RATE (gallons per hour)					
1	2	3	4	5	6	
12	.13	.26	.38	.51	.64	.77
24	.26	.51	.77	1.0	1.2	1.5
36	.38	.77	1.2	1.5	1.9	2.3
48	.51	1.0	1.5	2.1	2.6	3.1
60	.64	1.3	1.9	2.6	3.2	3.9
72	.77	1.5	2.3	3.1	3.9	4.6
84	.90	1.8	2.7	3.6	4.5	5.4
96	1.0	2.1	3.1	4.1	5.1	6.2

WILL NOT MEET MINIMUM DAILY CONSUMPTIVE USE RATES

HOURS of IRRIGATION	APPLICATION AMOUNT (acre-in) 24" FURROW SPACE 100' RUN					
	APPLICATION RATE (gallons per hour)					
1	2	3	4	5	6	
12	.09	.19	.29	.38	.48	.58
24	.19	.38	.58	.77	.96	1.2
36	.29	.58	.87	1.2	1.4	1.7
48	.38	.77	1.2	1.5	1.9	2.3
60	.48	.96	1.4	1.9	2.4	2.9
72	.58	1.2	1.7	2.3	2.9	3.5
84	.67	1.3	2.0	2.7	3.4	4.0
96	.77	1.5	2.3	3.0	3.9	4.6

WILL NOT MEET MINIMUM DAILY CONSUMPTIVE USE RATES

HOURS of IRRIGATION	APPLICATION AMOUNT (acre-in) 30" FURROW SPACE 100' RUN					
	APPLICATION RATE (gallons per hour)					
1	2	3	4	5	6	
12	.08	.15	.23	.31	.38	.48
24	.15	.31	.48	.62	.77	.92
36	.23	.48	.69	.92	1.2	1.4
48	.31	.62	.92	1.2	1.5	1.8
60	.38	.77	1.2	1.5	1.9	2.3
72	.48	.92	1.4	1.8	2.3	2.8
84	.54	1.1	1.6	2.2	2.7	3.2
96	.62	1.2	1.8	2.5	3.1	3.7

WILL NOT MEET MINIMUM DAILY CONSUMPTIVE USE RATES

PORTABLE OR DUAL SYSTEMS

Under highly erosive field conditions, portable pipe may be used temporarily, in conjunction with the established irrigation system, as a dual or secondary irrigation system. On both rill and sprinkler-irrigated fields, portable pipe improves irrigation efficiencies by providing the system flexibility needed to meet a variety of field and crop conditions and irrigation scheduling demands.

Application to Rill Systems

Portable pipe may be used in rill systems to: 1) replace head ditches where steeply sloped fields present an erosion hazard or where field and soil conditions result in water losses through subbing and evaporation, 2) provide more precise control over the application of water to the furrows, and 3) shorten the length of furrows during erosive periods of crop rotation (i.e., intertilled crops).

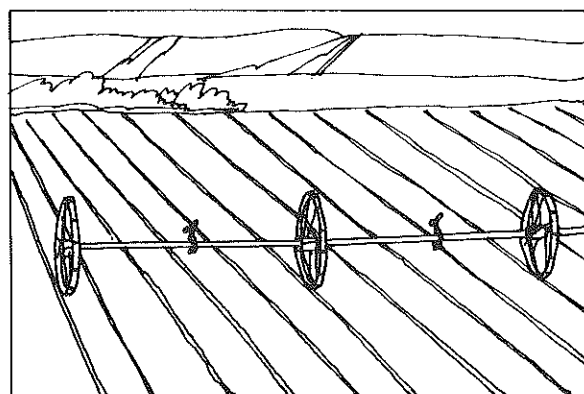
Types of portable pipe used for these purposes include pipe with gates, pipe with risers and/or valves, and flexible pipe with valves or gates.

As in all rill systems, water should be applied in nonerosive stream volumes. If the cutback method of irrigation is used, the stream should reach the end of the furrows in 20-30 percent of the total irrigation time to insure better distribution efficiency.

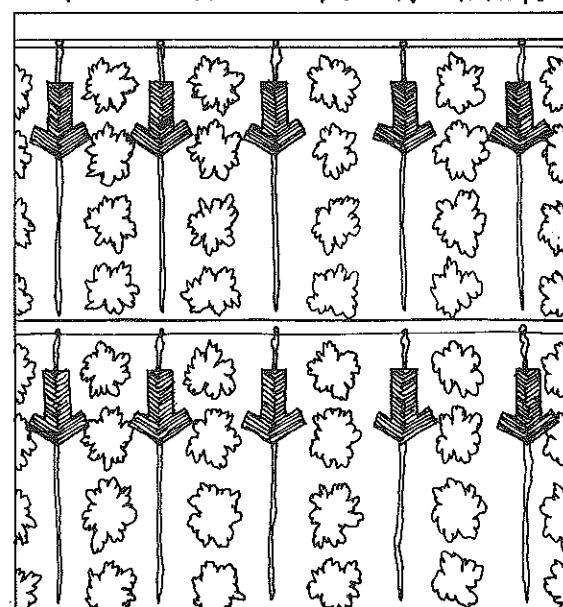
Application to Sprinkler Systems

Portable pipe may also be used with an established sprinkler system to: 1) lower the water application rate to more closely match a specific soil or crop intake rate, or 2) activate applied herbicides.

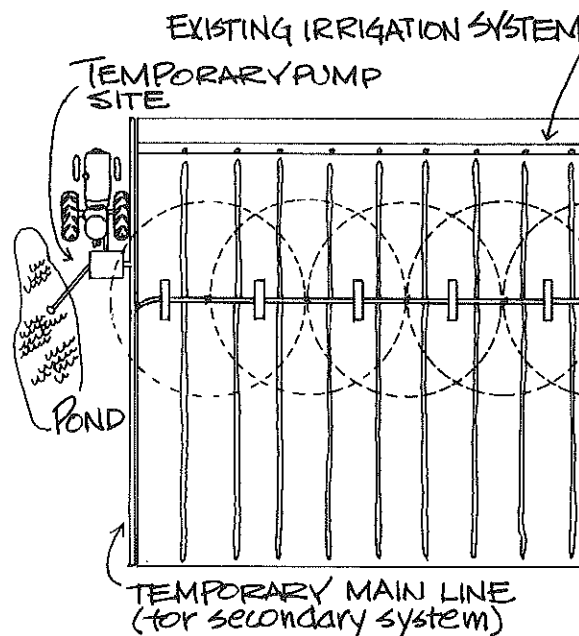
Types of portable or dual systems used in these cases include portable pumps, portable mainlines, and dual purpose mainlines (which may be buried). These devices may be attached directly to an existing portable handline or wheel line sprinkler system.



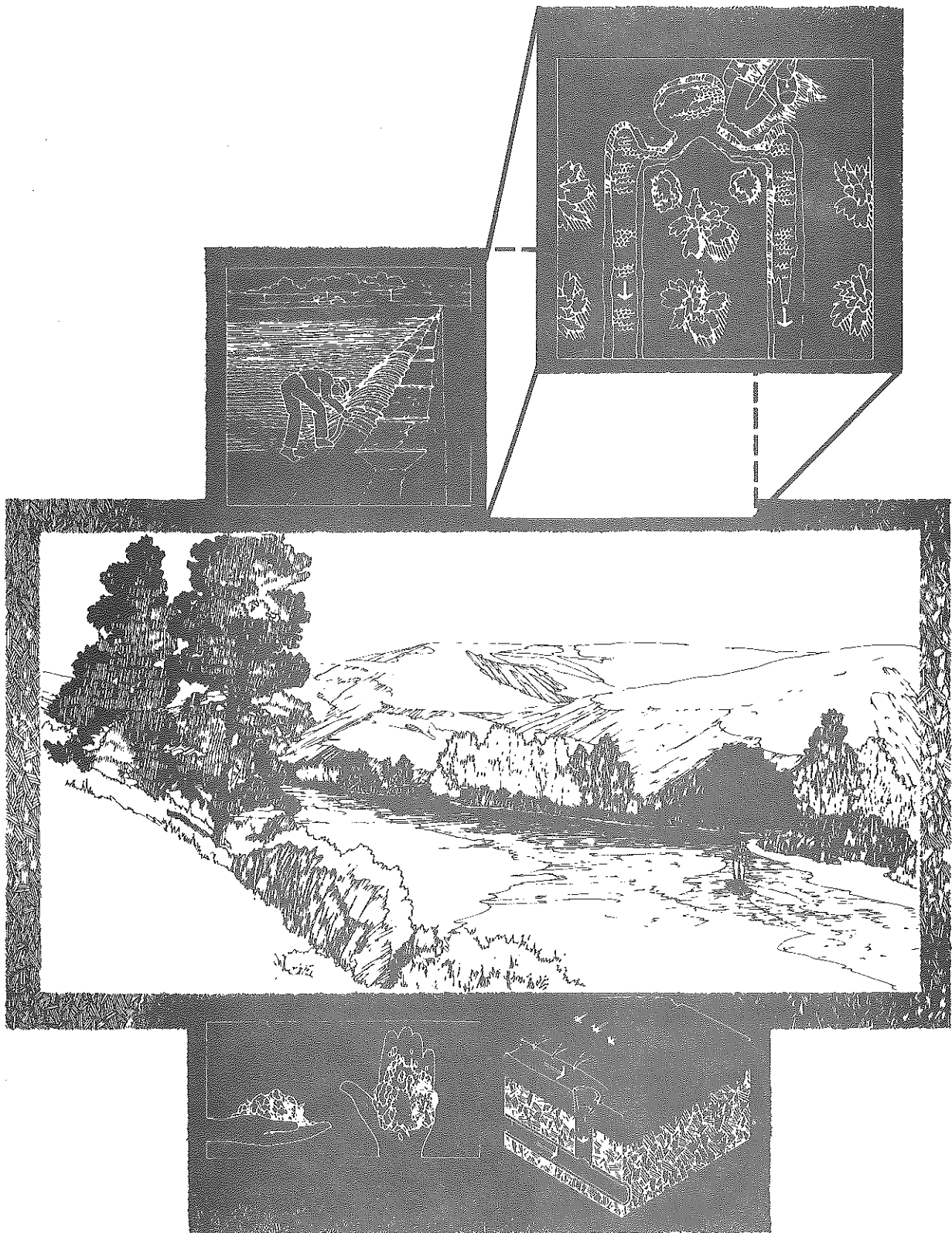
PERMANENT IRRIGATION SYSTEM



GATED PORTABLE PIPE USED TO REDUCE LENGTH OF RUN



Irrigation Water Management



IRRIGATION WATER MANAGEMENT

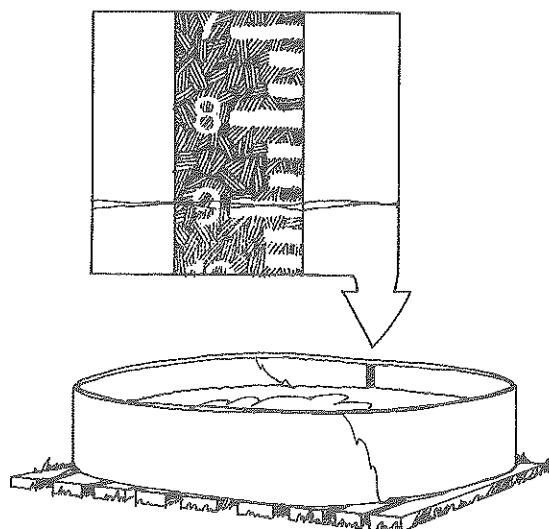
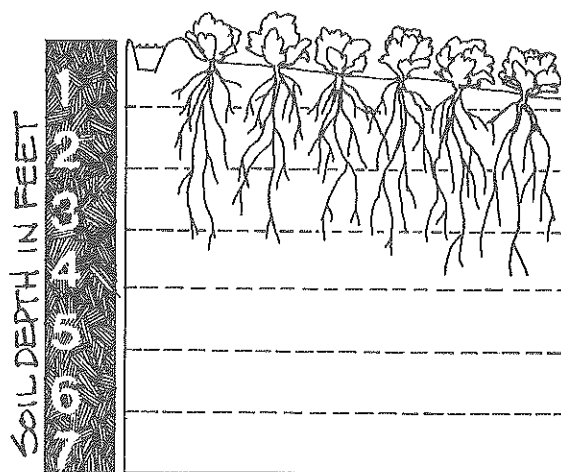
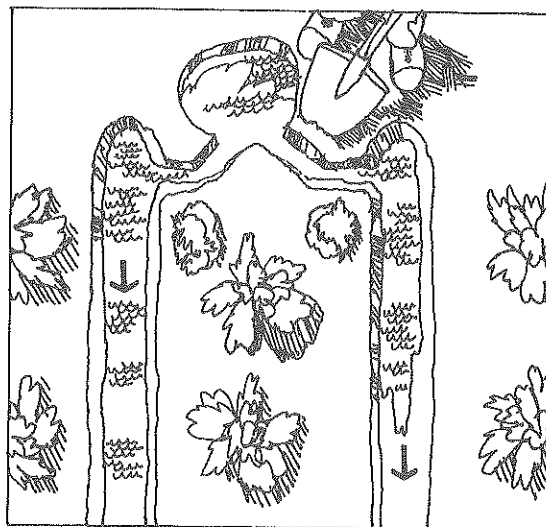
Applying the correct amounts of water, at the right times, in the most effective way, is one of the most challenging and important aspects of irrigated farming. Proper irrigation water management will not only fulfill the needs of the crops, but will prevent excessive soil loss and downstream water degradation.

Today, methods of scheduling and operating irrigation systems range from the basic “eyeball” approach to the advanced computer system. Whatever method is used, proper irrigation water management begins with a knowledge of irrigation systems, soils, crops, and climate.

Irrigation Scheduling

In order to schedule his irrigations, an irrigation manager must first determine how much water is needed and how often it must be supplied. Using information on his soil profile, its water holding capacity, crop rooting depth, and existing water content of the soil, he can calculate the available water reservoir in the soil. Information on the consumptive use rate of the crop and the daily evaporation rate tells him how rapidly this water reservoir is being depleted. These two measurements—current water reservoir and depletion rate—combine to indicate the amount and frequency of water application needed.

After determining the needed application amount and frequency for his crop, the manager must examine the constraints of his irrigation system and the available resources. The number of furrows or sprinklers and the amounts of labor and water available are important limiting factors. The irrigation schedule he designs must meet or exceed the predetermined application amount and frequency.



EVAPORATION PAN
INDICATES DAILY EVAPORATION RATE

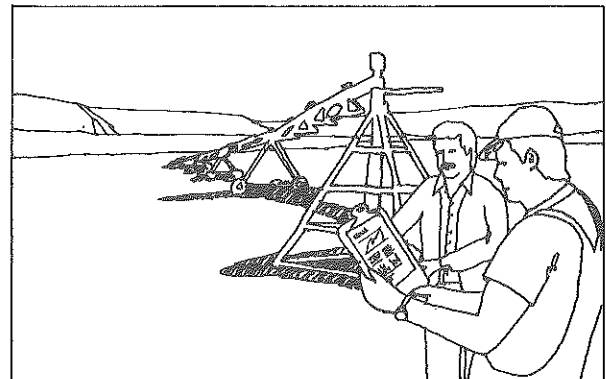
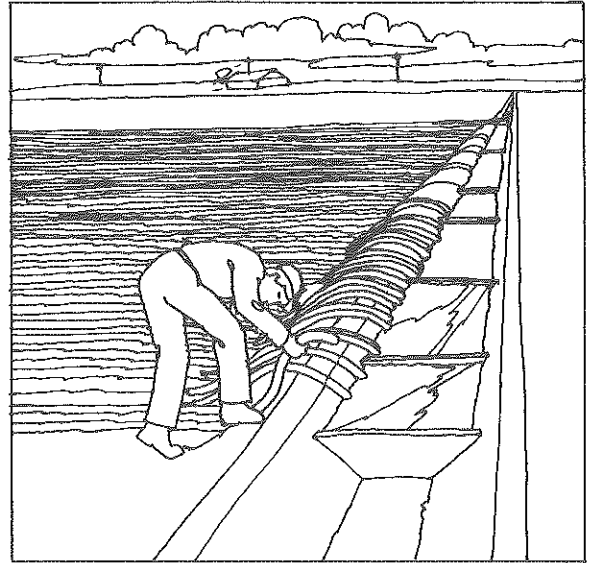
Rill systems rely heavily on the irrigation manager, or his irrigator, to regulate water application. Either the manager or the irrigator must determine what practices will best deliver the needed water without causing excessive erosion or surface runoff. Field slope, soil intake rate, and erodibility are the principal soil loss constraints to be considered.

Sprinkler systems by nature severely limit the alternatives for water application techniques. Water application rates can be altered to some degree, however, by changing the water pressure, sprinkler head spacing, and nozzle size.

Assistance

Several types of scheduling assistance are available:

- a) Local newspapers and radio stations regularly announce information on daily and cumulative evaporation rates.
- b) Local irrigation technical guides and irrigation slide rules (both available from offices of the Soil Conservation Service (SCS) and Cooperative Extension Service) allow a farmer to compute the entire irrigation schedule himself.
- c) Several government agencies, such as the Soil Conservation Service and the Cooperative Extension Service, can provide technical assistance ranging from soil analysis to computerized irrigation scheduling.
- d) Consulting firms can be contracted to plan all or part of a farmer's water management system.



CONSTANT RATE FLOW

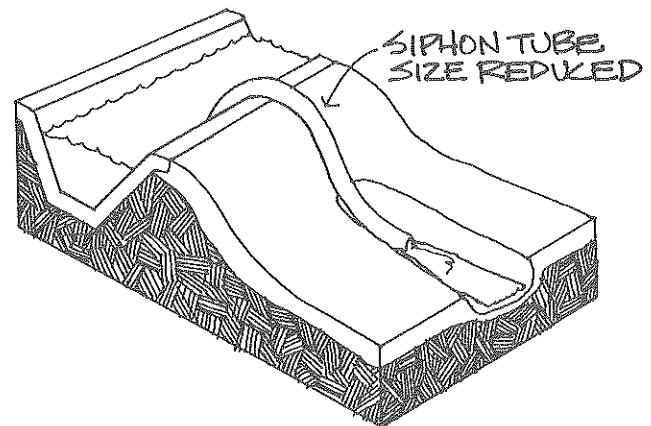
The constant rate flow method of water management consists of applying small, nonerosive streams for the entire irrigation set. Although this method may result in deep percolation water losses, it reduces erosion, total outflow losses, and the amount of labor required.

Constant rate flow can be applied to any rill irrigation system where the flow of water to the furrows can be accurately controlled. Because this practice works best on soils with low intake rates, it is recommended that it be used on either low intake rate soils or high intake rate soils which have been modified to lower the intake rate.

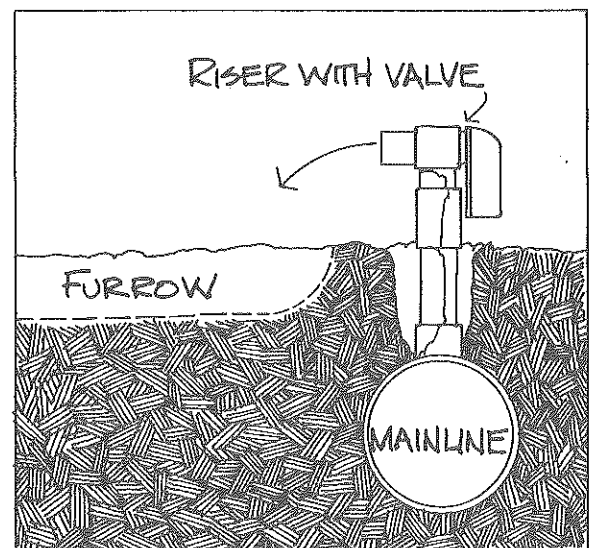
Stream volumes applied should be less than the maximum nonerosive stream size, yet should slightly exceed the soil intake rate on the given field. Exact stream volumes, however, will be influenced by field conditions, such as slope and furrow length and the length of irrigation set needed to meet the crop's water needs.

Furrows should be short enough so that the application of small constant streams does not result in lengthy irrigation set times or excessive water losses due to runoff and deep percolation.

The use of the constant rate flow method may require longer or more frequent irrigation sets to satisfy the water needs of the crop. Examples of gross water application amounts can be determined from this chart or an irrigation slide rule (available from local Soil Conservation Service and Cooperative Extension Service offices). A local irrigation guidebook should be used to confirm the proper application amounts.



SUBSEQUENT IRRIGATIONS



APPLICATION AMOUNTS (acre-in) 24" FURROW SPACING 900 FT RUN						
HOURS of IRRIGATION	INFLOW (GPM)					
	1	2	3	4	5	6
12	.69	1.28	1.92	2.56	3.21	3.85
24	1.28	2.56	3.85	5.13	6.42	7.70
36	1.92	3.85	5.77	7.70	9.63	11.55
48	2.56	5.13	7.70	10.27	12.89	15.40
60	3.21	6.42	9.63	12.89	16.05	19.26
72	3.85	7.70	11.55	15.40	19.26	23.11
84	4.49	8.98	13.48	17.97	22.47	26.96
96	5.13	10.27	15.40	20.54	25.68	30.81

EXCEEDS CAPACITY OF A HIGH WATER HOLDING
CAPACITY SOIL (WARDEN SILT LOAM)

NOTE: SHADED AREA WILL VARY WITH SOIL TYPE

FIXED-TIME IRRIGATION

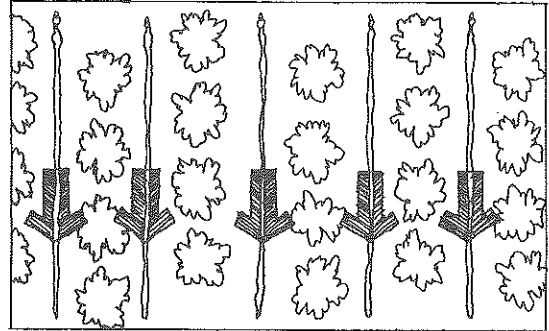
The fixed-time irrigation method is frequently used to reduce the hazard of erosion in freshly cultivated furrows. Small, constant rate streams are run alternately through adjacent furrows in 12-24 hour cycles. Although the streams may not reach the ends of the furrow in the first irrigation cycle, the cycles are repeated with successively higher volume streams until sufficient water is applied.

Fixed-time irrigation can be applied on any rill irrigation system.

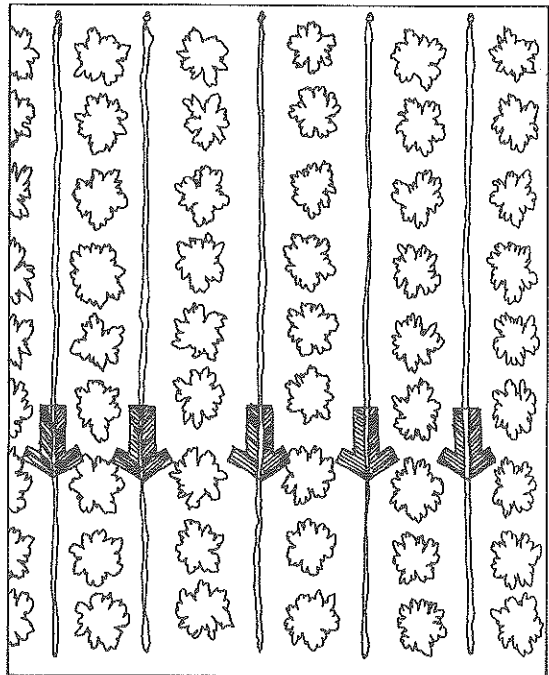
Constant rate stream volumes and all subsequent stream volumes must be nonerosive.

Examples of gross water application amounts can be determined from these charts. A local irrigation guidebook should be used to confirm the proper application amounts.

1st 12 Hr. Set



2nd 12 Hr. Set



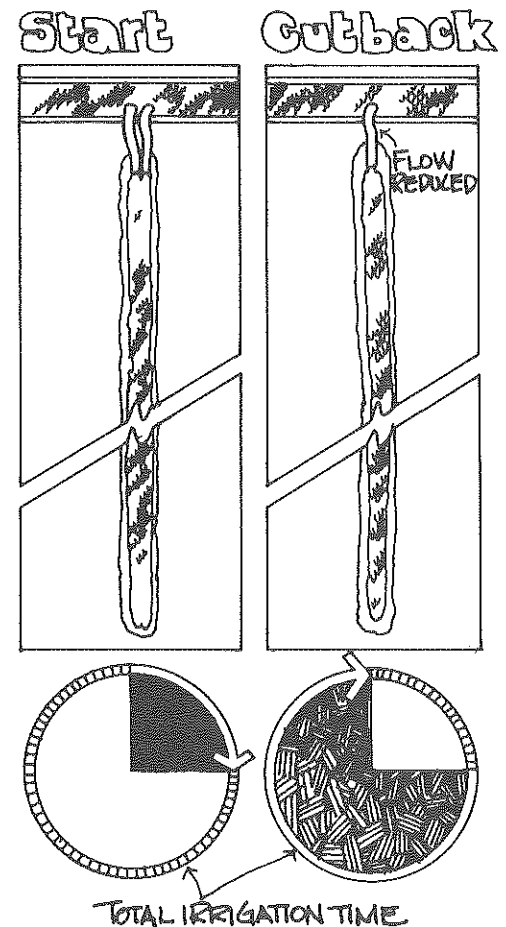
CUTBACK IRRIGATION

Cutback irrigation uses two or more sizes of streams run through the furrows during each irrigation set. Initially, large, nonerosive streams are run through the furrows in approximately 25 percent of the total irrigation time to insure that the entire length of each furrow receives water. The volume of the initial streams is then reduced or “cutback” to approximately equal the soil intake rate for the remaining 75 percent of the irrigation time to allow adequate saturation of the crop’s root zone.

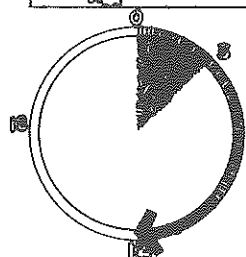
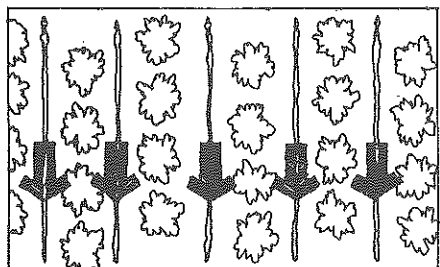
Cutback irrigation can be used on any rill irrigation system where the flow of water to the furrows can be easily controlled. The cutback method of water management provides good water use efficiency and reduces erosion and tailwater. Some amount of labor is required since an irrigator must be present to reduce the stream volume as the water reaches the ends of the furrows.

Initial stream volumes must be nonerosive, yet still allow the water to reach the end of the field in 20-30 percent of the total irrigation time. The volume of the cutback streams should not exceed the total intake rate of the furrows by more than 10 percent. Cutback irrigation may not be practical on fields where the initial stream volume cannot differ greatly from the cutback stream volume due to steep slope, low intake rate soils, etc.

At no time should the outflow volume exceed the inflow volume by more than 10 percent.

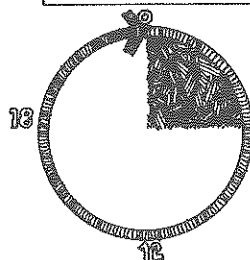
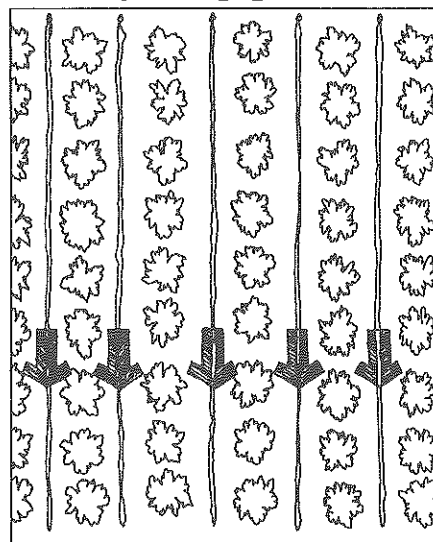


12 Hr. Set (AT SAME 9PM/FURROW)



WATER REACHES
END OF FURROW
IN 20% to 30% of
TOTAL IRRIGATION
TIME
(3 hrs. in this case)

24 Hr. Set (AT SAME 9PM/FURROW)



WATER REACHES
END OF FURROW
IN 20% to 30% of
TOTAL IRRIGATION
TIME
(6 hrs. in this case)

MAXIMUM NON-EROSIVE STREAMFLOWS			FURROWS*per CUBIC FT/SEC.
% SLOPE (ft/100')	FRESHLY CULTIVATED FURROWS	SLICKED or PRE-IRRIGATED FURROWS	FURROWS WITH COVER
0-.5%	5-6.5	7-8.5	10-12
	70-90	53-65	38-45
.5-1%	4-5	6-7	8-10
	90-113	65-75	45-56
1-2%	3-4	5-6	6.5-8
	113-150	75-90	56-70
2-3%	1.5-3	3.4-5	4.5-6.5
	150-300	90-129	70-100
3-5%	.5-1.5	2-3.5	2.5-4.5
	300-900	129-225	100-180

* OR SIPHON TUBES

5-6.5	GALLONS PER MINUTE
70-90	FURROWS

MODIFIED FLOW

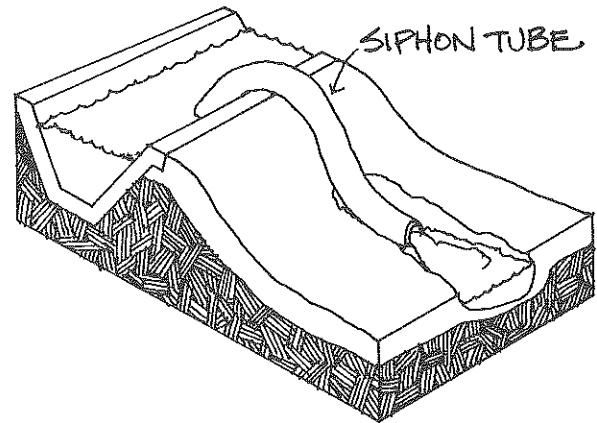
During the first irrigation following cultivation, large siphon tubes are used to run high volume nonerosive streams through the furrows. On all subsequent irrigations, the volume of the streams is permanently reduced by replacing the large siphon tubes with smaller tubes or by placing a plug, or "modifier," in the large siphon tubes to reduce the tubes' diameters.

The modified flow method of water management can be used on all rill irrigation systems which use siphon tubes to regulate the application of water to the furrows. The modified flow concept may be used with buried pipe systems using smaller flows after the first irrigation following cultivation.

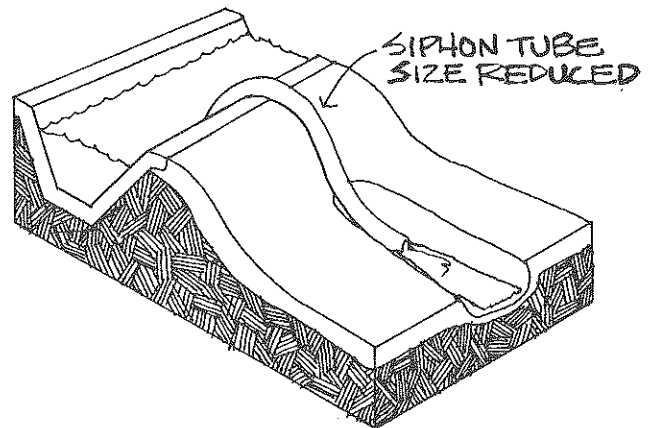
Initial stream volumes must be nonerosive, yet still allow the water to reach the end of the field in 20-30 percent of the total irrigation set time.

Volumes of the modified streams should not exceed the intake rate of the furrows by more than 10 percent. (Outflow should not be more than 10 percent of inflow.)

INITIAL IRRIGATION



SUBSEQUENT IRRIGATIONS



PRESSED (SLICKED) FURROWS

Compacting the soil in the irrigation furrows can greatly improve irrigation efficiency by lowering the soil intake rate. The use of pressed or slicked furrows increases the advance rate of the streams, allowing small, nonerosive streams to be applied and run through longer furrows at a faster rate.

Although pressed furrows are usually used on high intake rate soils, they are also effective on the following soil types:

Coarse

Sand
Fine Sand
Loamy Sand
Loamy Fine Sand

Medium

Sandy Loam
Fine Sandy Loam

Light

Very Fine Sandy Loam
Loam
Silt Loam*

*Intake of this soil type should be carefully evaluated before the furrows are modified. Overcultivation and/or low organic matter content in these soils may cause compaction and infiltration problems.

This practice is not recommended for use on the following soil types because of their low intake rates:

Heavy

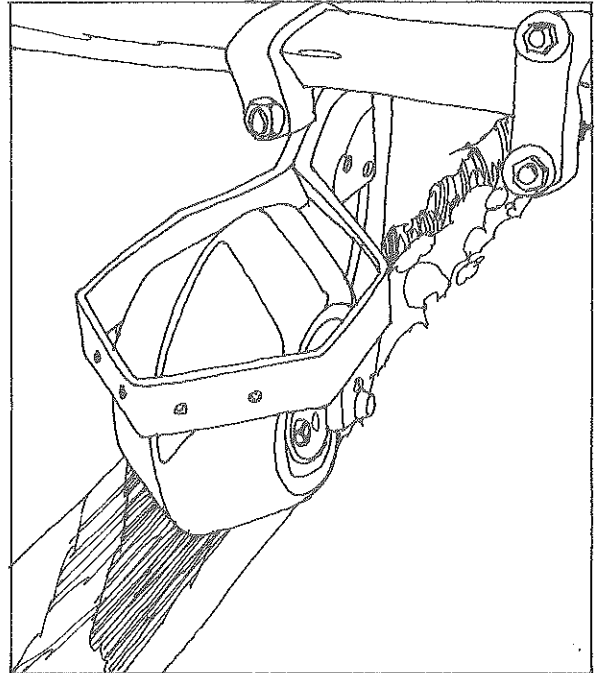
Clay Loam
Sandy Clay Loam
Silty Clay Loam

Medium

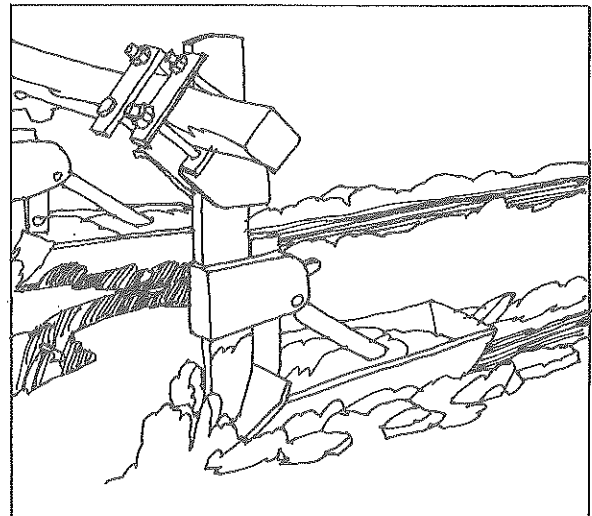
Sandy Clay
Silty Clay
Clay

Stream volumes must be nonerosive. Because of the streams' increased advance rates, furrows should not be slicked in silt loam soils on slopes of greater than 3 percent or in other soil types on slopes greater than 5 percent.

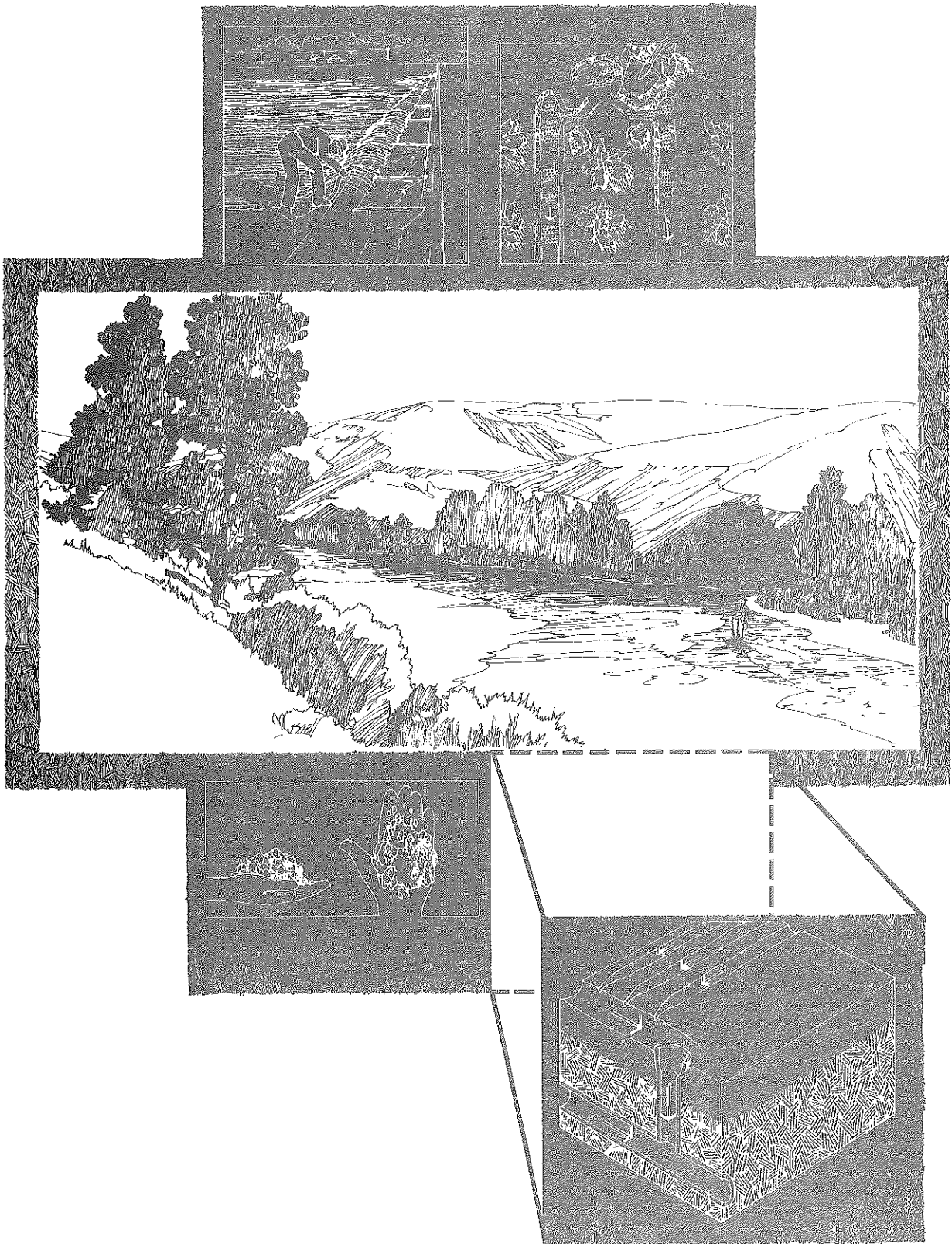
Several types of furrow modification devices are available to create pressed furrows.



PRESS WHEEL



FURROW SLICKER



Tailwater Management

TAILWATER MANAGEMENT

Good irrigation water management does not end with the application of water to the field. The tailwater, or runoff, produced by most irrigation systems may result in erosion and water quality degradation if left unmanaged. Proper management of tailwater can protect collection ditches from erosion, reclaim soil from return flows, and increase water use efficiencies through reuse.

In order to transport the tailwater safely to a discharge point, treatment facility, or reuse system, a collection system should be installed on nonerosive grades and designed to carry water at nonerosive speeds.

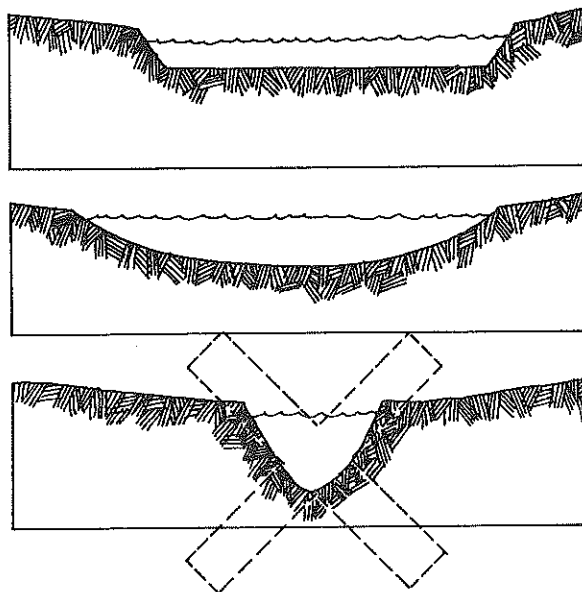
Where steep slopes or large volumes channel the water into narrow streams, collection ditches should be wide and flat to dissipate the erosive energy of the stream. Both parabolic and trapezoidal shape ditches are effective.

Different soil types are more susceptible to erosion and, therefore, will require different system designs. Fine textured soils do not erode as easily as coarse textured soils and can carry higher stream velocities.

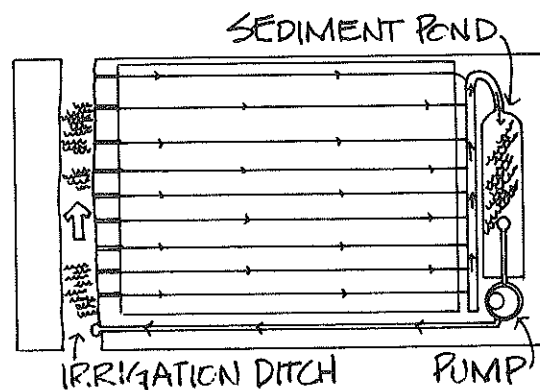
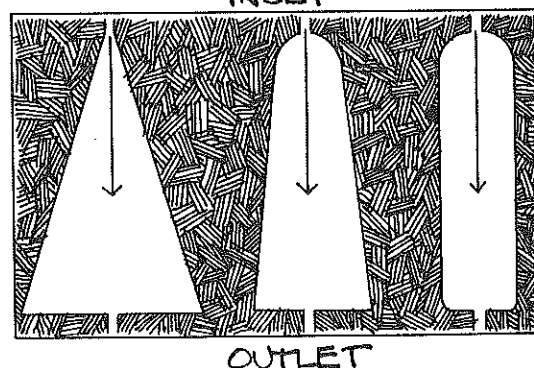
Adding vegetation to the soil surface will further protect the soil from erosion.

Sediment basins and reuse (or repump) systems are optional as final measures in tailwater treatment. Although sediment basins may be installed to desilt incoming water, they are primarily used to desilt tailwater and reclaim settleable sediments. Reuse systems reduce the amount of tailwater from a field by transporting the runoff back to the head of the field for reuse within the farm unit.

NON-EROSIVE COLLECTION
DITCH SHAPES



EFFICIENT SEDIMENT POND
SHAPES

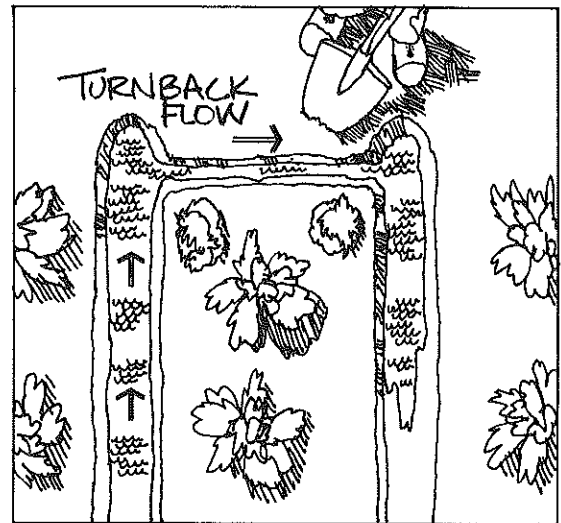


TURN-BACK FLOWS

Tailwater may be reduced or eliminated and water infiltration at the lower end of the field increased through the use of turn-back irrigation. Earthen check dams are constructed at the end of the furrows to stop or divert ("turn-back") the flow of tailwater from a field.

Turn-back irrigation may be applied to any rill irrigation system laid out on a relatively flat field. This practice is especially valuable on low intake rate soils to increase water infiltration and reduce runoff.

A substantial amount of labor is involved in the application of this practice. Irrigators must be available to install check dams and possibly to divert the stream into an adjacent furrow as the stream reaches the end of the field. Once the stream reaches the end, the turnback stream's volume must be reduced to prevent waterlogging at the furrow's lower end.



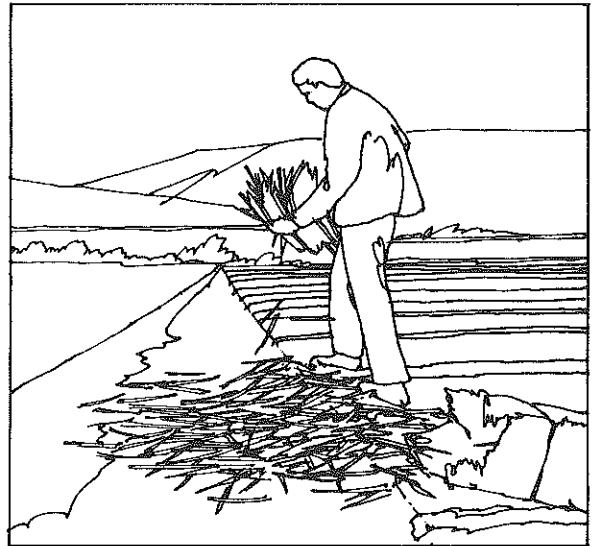
MULCHING

Straw, crop residue, gravel, or other coarse material may be mixed with the soil in a collection ditch to protect the ditch from erosion. This easily accomplished practice, termed mulching, reduces the erosive velocity of the tailwater and, consequently, settles suspended sediments.

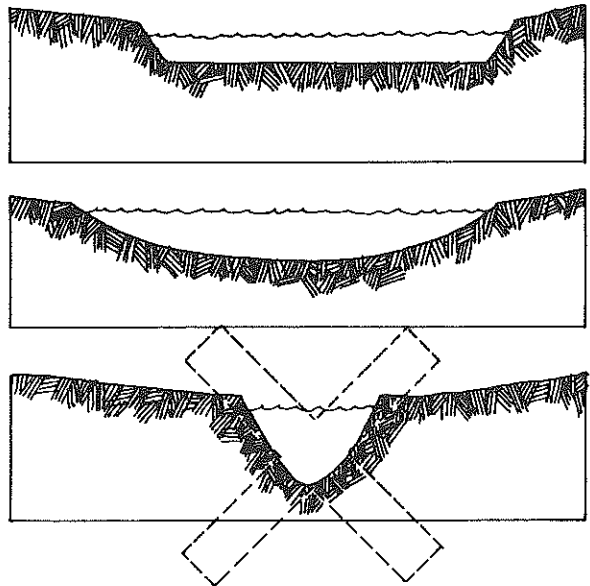
Collection ditches may be mulched wherever they must carry erosive volumes of tailwater or must be laid out on erosive grades over 2 percent.

Wide, flat shapes are the most effective designs for mulched collection ditches.

The mulching material should be spread uniformly in the collection ditch and may be partially disced into the soil to secure it. Approximately two to three tons of mulching material should be applied per acre of collection ditch area. (For example, a ten-foot wide ditch would require two to three 50-pound bales of straw per 100 feet.)



NON-EROSIVE COLLECTION
DITCH SHAPES



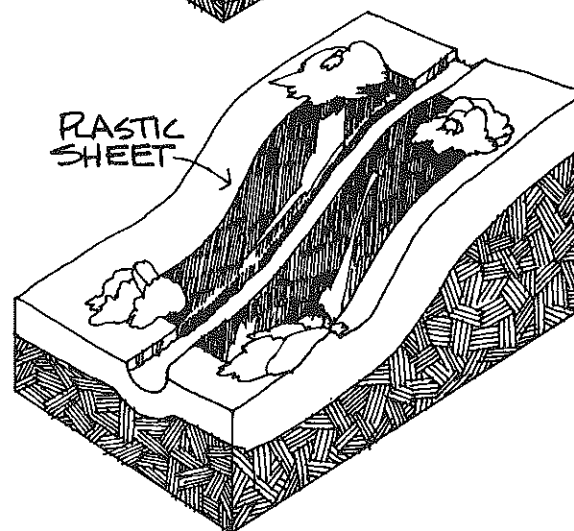
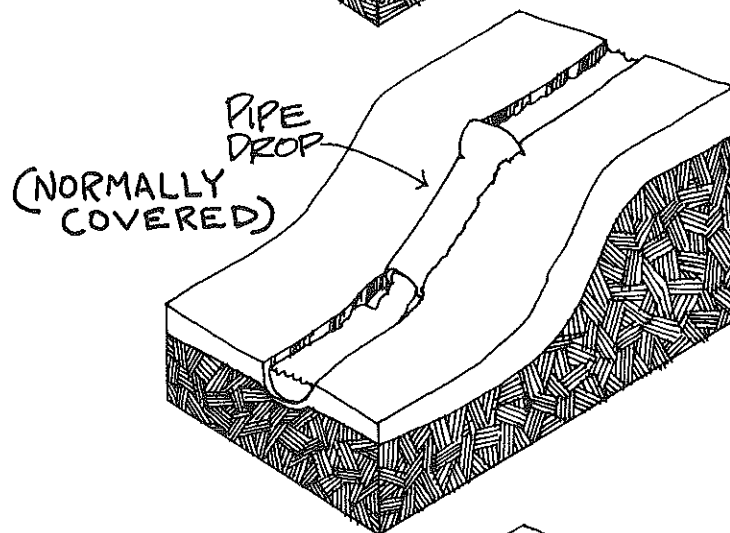
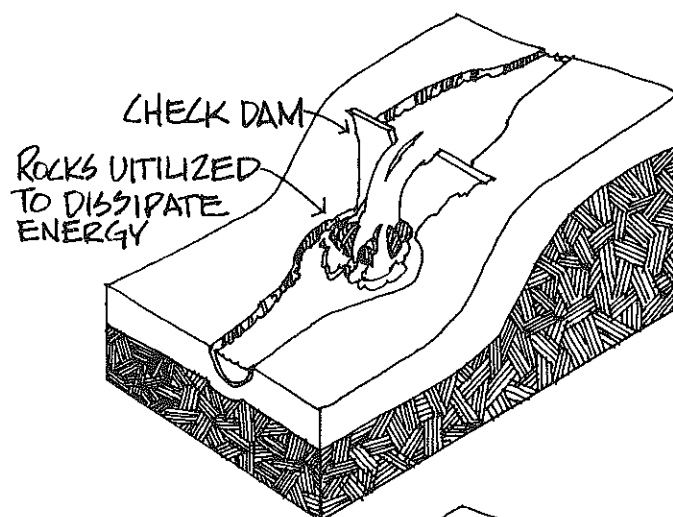
DROP STRUCTURES

Drop structures may be installed in steeply sloped collection ditches to reduce the velocity of the tailwater and the hazard of erosion. Temporary or permanent check dams, installed at intervals in a collection ditch, reduce the steep grade of the ditch to a series of shorter, nonerosive grades. Check dams slow the tailwater before it flows over the dams, into pools, and continues on to the next drop structure.

As alternative types of drop structures, pipe drops or plastic sheet linings may be used in place of check dams to safely transport the tailwater down the elevation drop.

Drop structures may be used in collection ditches on slopes up to 5 percent. Elevation and spacing of the drop structures should maintain nonerosive grades in the ditch. The structures should be spaced close enough to prevent tailwater from reaching erosive velocities.

Above each check dam, small sediment basins may be dug to slow the stream and settle sediments. Small pools, stones, or a series of baffles should be provided immediately below each drop structure to dissipate the erosive energy of the flowing water. Where drop structures are permanently installed, sod waterways or perennial vegetative strips may be planted to further protect the collection ditch.



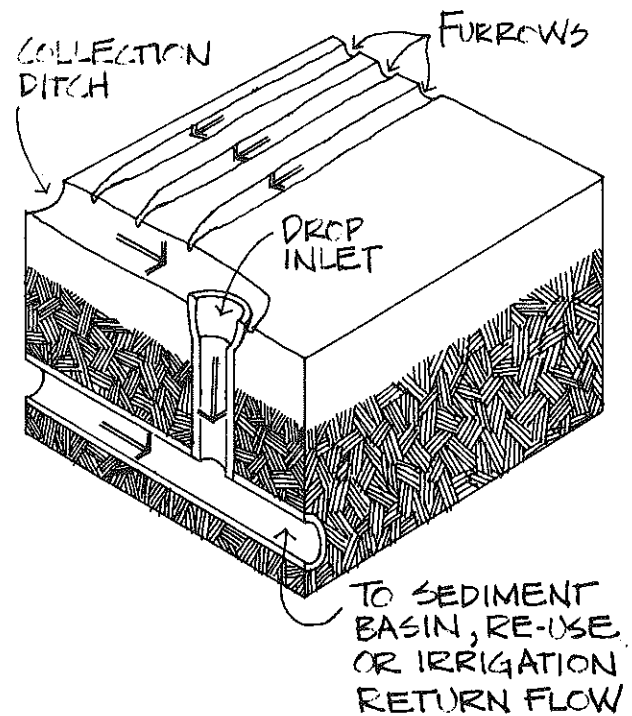
BURIED PIPE

Where collection ditches must carry large volumes of tailwater over long distances or steeply sloped ground, buried pipe may be an effective method of reducing erosion. The tailwater passes through a drop inlet in the collection ditch and into a buried pipe to be transported to a discharge outlet, reuse system, or sediment basin.

Drop inlets to the buried pipe should be installed to avoid the accumulation of erosive volumes of tailwater. The correct spacing for drop inlets can be calculated by 1) computing the total flow volume (in gallons per minute) by multiplying the number of irrigated furrows by the volume of tailwater flowing from each furrow, and then 2) determining the maximum nonerosive run length (drop inlet spacing) given the slope of the ditch and the total volume of tailwater flowing in the collection ditch.

To prevent debris from entering buried pipe, drop inlets may be screened or used in conjunction with sediment basins. To prevent the deposit of fine sediment in the pipe, the capacity and design of the buried system should allow a stream velocity of at least 1.5 feet per second within the pipe. The use of other collection ditch protection practices, such as mulching or vegetative strips, will also help to reduce maintenance and prolong the life of the buried pipe system.

During particularly erosive periods of the crop rotation, sediment basins, vegetative filter strips, and other desilting measures may be needed to treat the tailwater at the pipe's discharge point.



VEGETATIVE STRIPS

Planting annual or perennial vegetation (grasses or legumes) in collection ditches can help settle sediments in the tailwater and protect the ditch from erosion. These vegetative strips are termed “filter strips” when used primarily to remove sediments, and are called “grassed waterways” when used to transport erosive volumes of tailwater safely off the field.

In rill or sprinkler systems, vegetation can be established in collection ditches laid out on slopes steeper than 2 percent, carrying erosive volumes of tailwater or water containing large amounts of sediment.

Before seeding, ditches should be shaped into wide, flat shapes to more effectively reduce stream velocity and to settle and retain sediments.

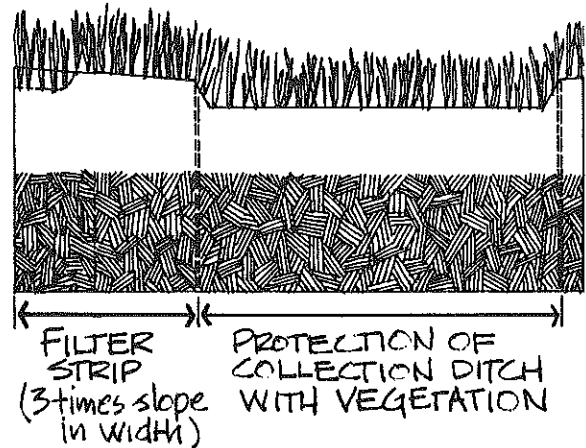
Filter Strips

Where sediment content in the tailwater is high, annual vegetation may be preferable to perennial plants. Annuals grow rapidly, even through sediment, making them very effective in removing large amounts of sediment. Inexpensive and easily established, annuals are well-suited for planting in ditches which require yearly cleaning and reshaping.

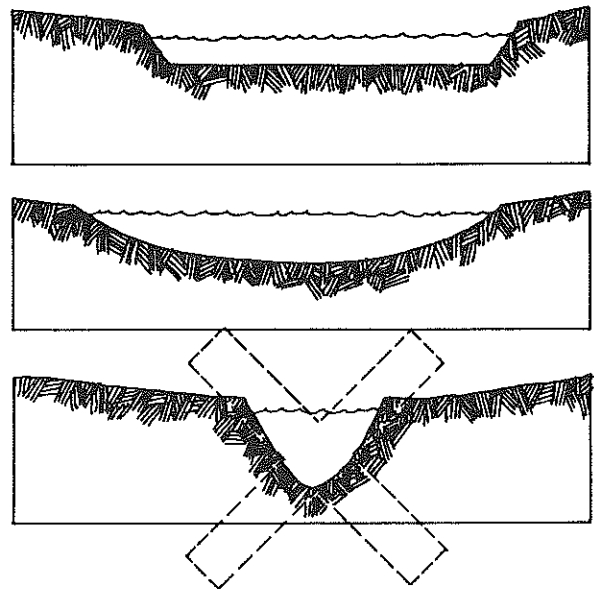
Annual vegetation should be broadcast seeded. Planting seeds in drilled rows may increase the hazard of erosion until the vegetation is established.

The filter strip should be no less than nine feet wide. On steeper slopes, the width should be equal to three times the slope. (For example, on a field of 5 percent slope, the filter strip width should equal $3 \times 5\%$, or 15 feet.)

Annuals adaptable for filter strips include spring grains (seeded in the fall) and fall grains (seeded in the spring). Extension



NON-EROSIVE COLLECTION DITCH SHAPES



Service, Soil Conservation Service, and conservation district personnel can assist in the choice of grasses best suited to meet individual soil types, seeding rates, etc.

Grassed Waterways

Perennial vegetation (grass sod) is recommended for collection ditches transporting large, erosive volumes of tailwater. Due to difficulties in cleaning, it is not recommended where large sediment deposits are expected.

Grassed waterways are effective in reducing erosion on all slopes.

Perennial vegetation, seeded in the fall, adaptable for grassed waterways include:

- Sherman Big Bluegrass
- Whitmar Wheatgrass
- Nordan Crested Wheatgrass
- Siberian Wheatgrass
- Greenar Wheatgrass
- Topar Pubescent Wheatgrass
- Kentucky Bluegrass
- Slender Wheatgrass
- Tall Wheatgrass
- Smooth Brome
- Alta Fescue
- Orchard Grass
- Tall Oatgrass
- Creeping Red Fescue

Extension Service, Soil Conservation Service, and conservation district personnel can assist in the choice of grasses best suited to meet individual soil types, seeding rates, etc.

Measures should be taken to protect the areas at the ends of grassed waterways from erosive velocities and volumes of tailwater.

SEDIMENT BASINS

Substantial amounts of sediment may be removed from incoming irrigation water or tailwater through the use of sediment basins. These shallow ponds reduce the velocity of the water as it flows through, causing the sediments to settle out and be collected in the basin.

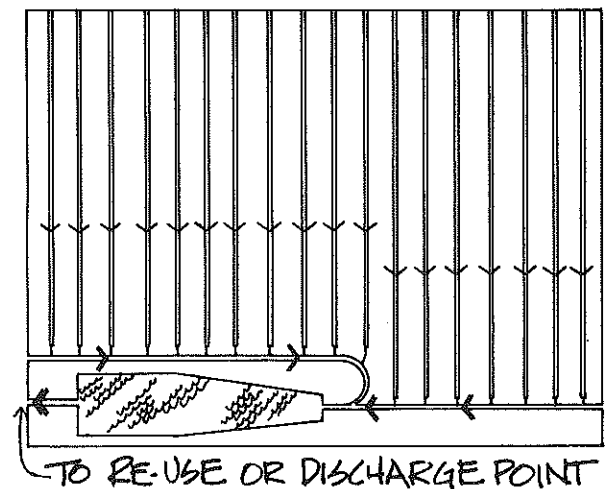
Sediment basins may be used with any type of sprinkler or rill irrigation system. Although they are effective with all types of soil, they are most efficient on coarse textured soils which settle rapidly.

Basins may be constructed at the point where the water is delivered to the field if the water requires desiltation before use. In many cases, numerous small sediment basins, interspersed throughout a farm unit, may more effectively reduce sediment loss and maintenance problems. If the tailwater is to be desilted before it leaves the farm unit, basins may be constructed at the field's discharge point.

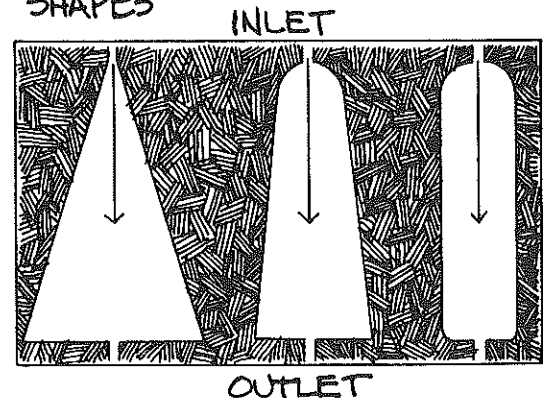
Sediment basins may be constructed either by earthen dams or by excavation of a shallow pit.

If possible, basins should be capable of retaining the total amount of sediment resulting from irrigation season, yet still provide effective operation at the end of the season.

Dimensions of sediment basins vary depending upon the farm conditions, i.e., soil type and crop grown. The basins may be any shape, provided the distance between the inflow and outflow points is maximized. The width depends primarily on the type of cleaning equipment to be used. The depth of the basin should not exceed six feet in order to avoid maintenance problems and hazards to livestock and people.



EFFICIENT SEDIMENT POND SHAPES



REUSE SYSTEMS

The reuse of irrigation water provides more efficient water use by collecting and transporting tailwater for reuse within the farm unit. Reuse systems range in design from those which use gravity to collect and convey tailwater to a lower field to systems which pump tailwater back to the delivery point for mixing and reuse with incoming irrigation water.

Reuse systems may be utilized on any irrigation system in which tailwater can be collected at a common point. These systems are especially valuable in improving water use efficiencies on fields with low intake rate soils.

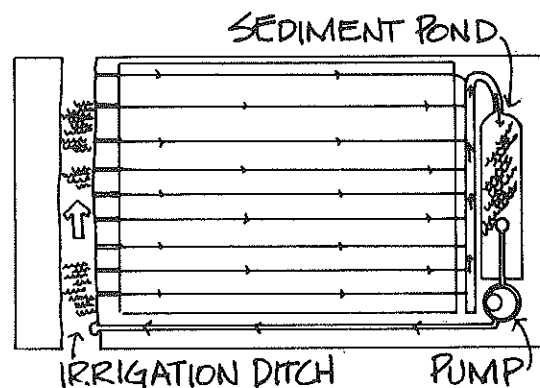
An agriculture consulting firm or an engineer familiar with local conditions and technical specifications should be consulted on the design of a reuse system.

The size of a holding pond needed depends on the volume and frequency of the incoming water. Large, steady flows are easily managed, requiring a moderate size pond. Sporadic flows, on the other hand, require larger holding ponds. In some cases, it may be necessary to collect water from several farm units to make the system practical.

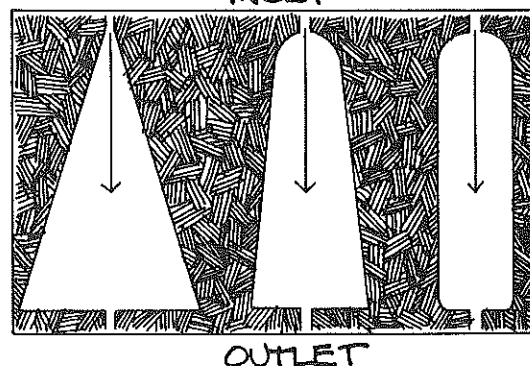
If the system is intended to desilt the water prior to use, the holding pond must be large enough to act as a sediment basin.

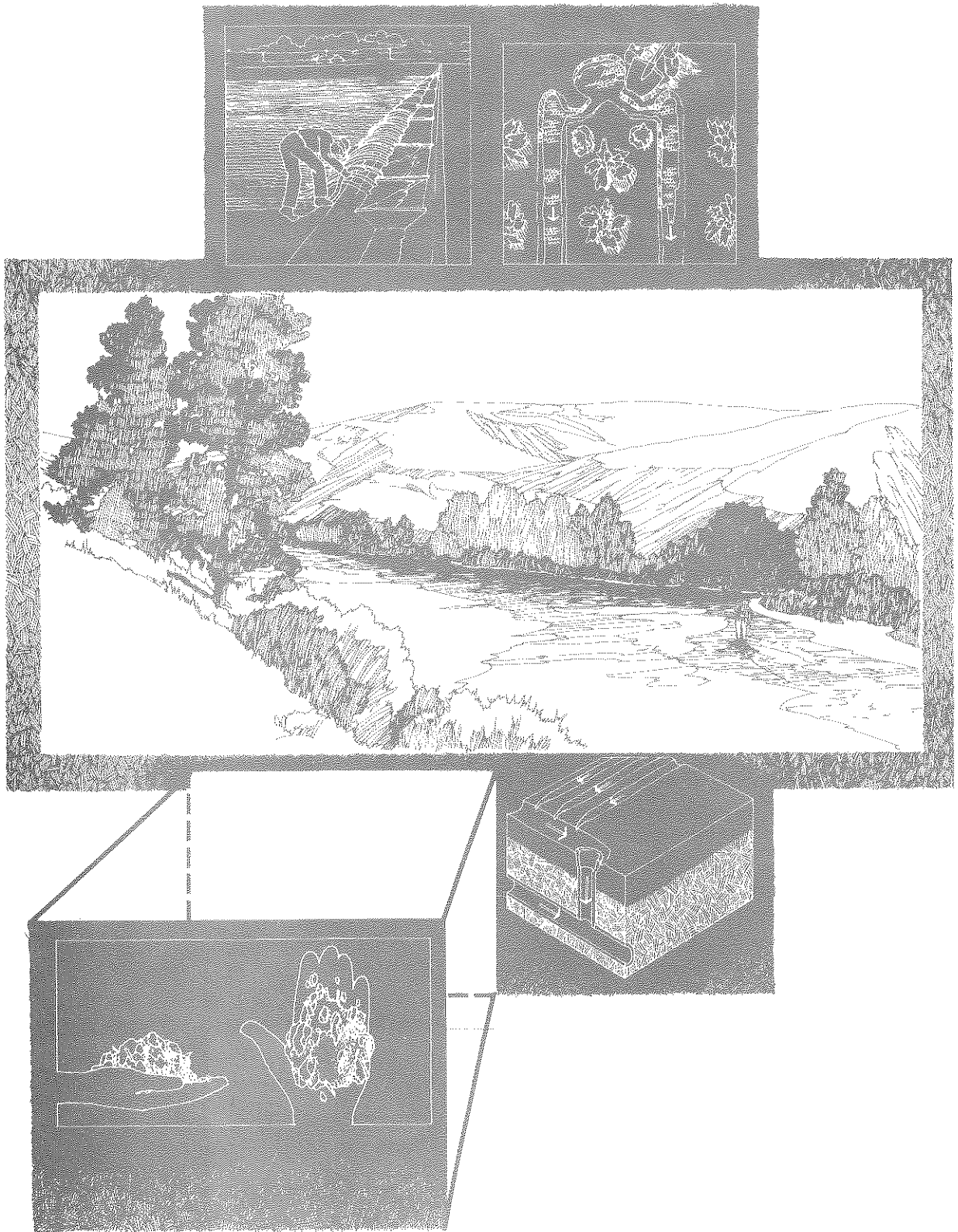
Low speed pumps should be utilized in order to minimize wear on electric systems. The volume and frequency of the inflow and the nature of the pumping operation (continuous or intermittent) will determine the appropriate size of pump needed.

If desilting ponds are to be used, they should be capable of allowing one hour settling time. All other specifications should follow those outlined for sediment basins.



EFFICIENT SEDIMENT POND SHAPES





Soil Management

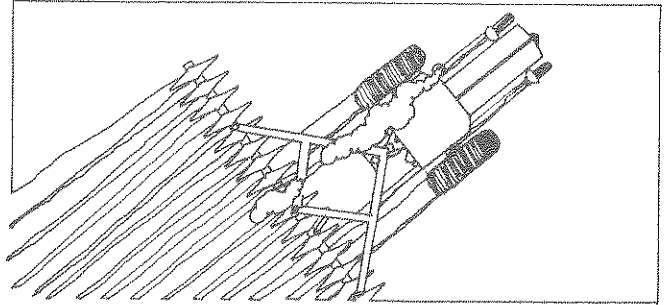
SOIL MANAGEMENT

Agricultural water quality is greatly affected by the condition of the soil irrigated. Soil management, therefore, is an essential complement to water management.

Tillage, the practice of breaking up the soil structure to prepare a seedbed and control weed growth, can impair water quality. Overcultivation can result in powdery, erodible surface soils. Poor tillage practices repeated over time can alter the subsurface soil structure and cause intake rate and water runoff problems.

Unprotected soil surfaces are often susceptible to erosion by wind or water. Organic matter or crop residues, maintained on the surface, can reduce the erodibility and increase both the intake rate and water holding capacity of the soil.

Tillage operations can be combined with residue management practices to yield a substantial savings to the farmer in terms of labor, fuel, soil, and water.



REDUCED TILLAGE

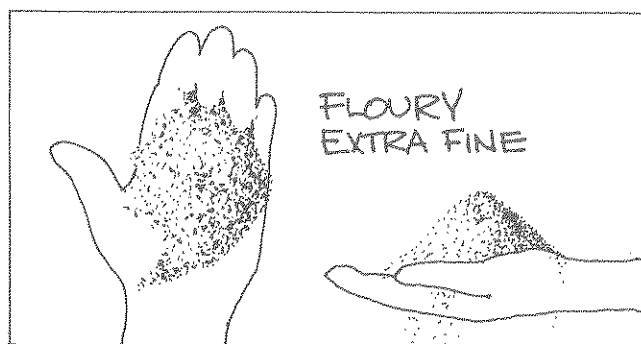
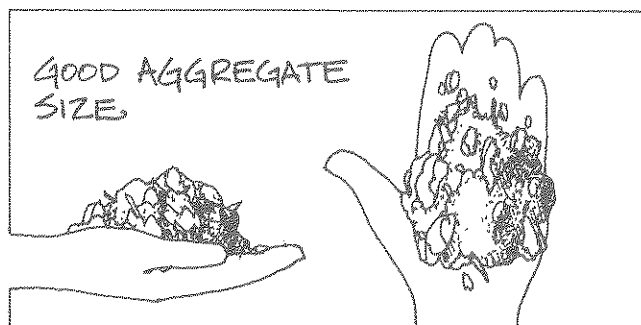
Both soil and water conservation efforts are aided by a reduction in the number of seasonal tillage operations. The practice of reduced tillage maintains large soil particles and large amounts of crop residue on the field surface, thus reducing excessive runoff and soil movement.

Reduced tillage is applicable to all soil types and farming operations. Because it increases water infiltration and eliminates excessive soil compaction, reduced tillage is especially recommended for use on low intake rate soils susceptible to overcultivation.

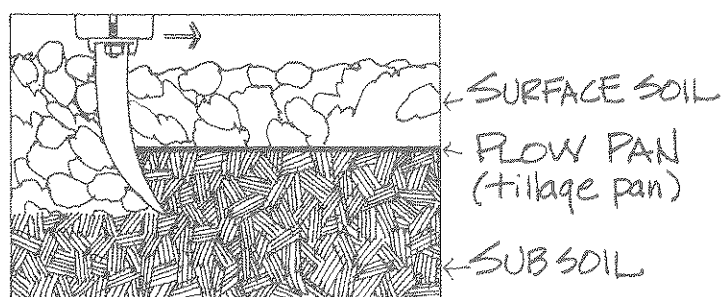
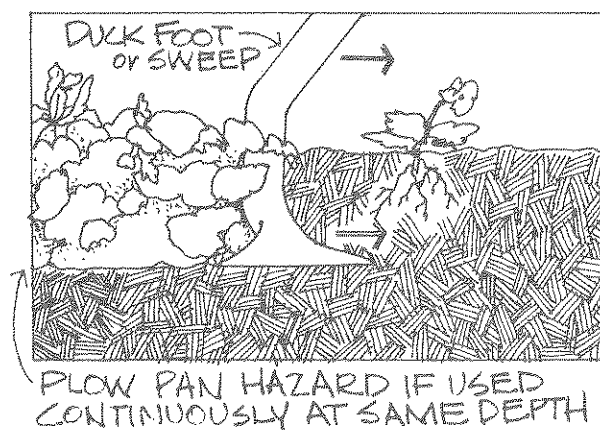
Subsurface and deep tillage operations may also be carried out with a minimum of detrimental impact to the soil surface. Tractor-drawn subsurface tillage implements, such as chisel plows, duck feet, and sweeps, may be used to break up the upper profile of the soil. This type of sub-surface tillage allows the soil and the crop residues on the surface to remain relatively undisturbed.

Over several seasons, tillage operations may create a compact layer of soil below the tillage depth. To avoid reduced intake rate and runoff problems, irrigated fields should be deep tilled every three years (possibly more often with row or intertilled crops). Deep tillage operations, such as chiseling and subsoiling, help increase the soil intake rate and allow water percolation below the root zone, while minimizing disruption of the soil surface.

NON-EROSIVE SOIL SAMPLE



EROSIVE SOIL SAMPLE



RESIDUE MANAGEMENT

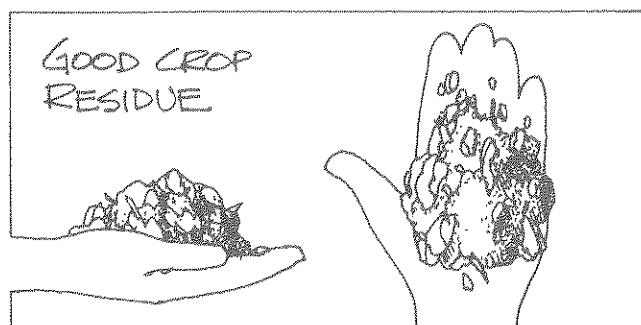
Conscientious management of crop residue can protect both the farmer's water and soil resources. By including high residue crops in the crop rotation and maintaining large amounts of organic material on the field surface, he can increase the intake rate and reduce erosion of his soil.

Although residue management may be practiced on all fields, it is strongly recommended for medium-textured soils on slopes of 2 percent or greater.

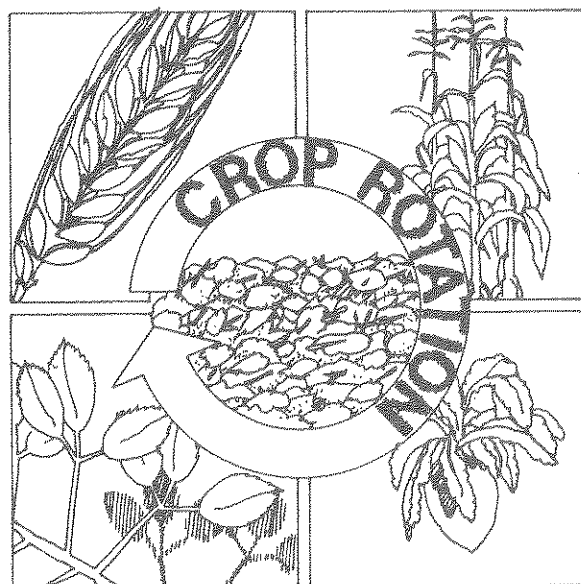
High residue crops, such as corn and small grains, should be included in the cropping rotation. These slow-decomposing crops leave organic residue on the soil surface where it is most effective in increasing soil intake rate and reducing erosion and runoff. Cover crops may also add some crop residue to the soil. Green manure crops, if handled properly, will add residue in addition to providing valuable nutrients to the soil.

If high residue crops may not be grown in certain critical erosion areas, crop residues may be brought to the site and mulched into the soil.

The amount of surface residue left on a field or mulched into the soil must be sufficient to prevent erosion, but not hinder the flow of water through the furrow. Excessive amounts of crop residues on steep slopes may cause the irrigation streams to "break through" and flow across adjacent furrows.



SMALL GRAINS ROW CROP



ALFALFA

ROW CROP

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